DOCTOR OF PHILOSOPHY

Fetal responsiveness to auditory and tactile stimulation

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Fetal responsiveness to auditory and tactile stimulation

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Declaration

I declare that I am the author of this thesis and that, unless otherwise stated, all references cited have been consulted by me. The work, of which this thesis is a record, has been carried out solely by me and has not been previously accepted for a higher degree.

………………………………………………………

Date, Signature: Viola Marx

Abstract

The aim of this thesis was to examine fetal behavioural responses to auditory and tactile stimulation. Responses were examined for the second- and third-trimester fetuses (second-trimester ≤ 27 gestational weeks (wGA), third-trimester >27 wGA), in both experiments, respectively.

Experiment 1 of this thesis examined fetal behavioural responses to the mother's recorded and live voice, contrasting findings to an environmental sound and silent control conditions. Behavioural responses of 30 fetuses trimester (20-33 wGA, N = 13 in the 2nd and N = 17 in the 3rd trimester) Were examined in the following conditions were explored: (1) mother's live, (2) and recorded voice, (3) an environmental sound, and (4) a silent control condition.

Findings showed the strongest responses to maternal sounds as well as differential responses between gestational age groups. Younger fetuses displayed an arousal response to maternal voice, whereas third-trimester fetuses displayed an orientating response.

The aim of Experiment 2 was to examine whether fetuses can differentiate between different human sources of tactile stimulation of the maternal abdomen. Behavioural responses of 28 fetuses (20-33 wGA, N = 15 in the 2nd and N = 13 in the 3rd trimester) were examined across four conditions: (1) mother's, (2) father's, and (3) stranger's touch, as well as a (4) silent control condition. Differential responses to the tactile stimulation were found, especially in reaching of the uterine wall, and self- touch across the four conditions. Third-trimester fetuses touched the uterus wall for significantly longer than fetuses in the second-trimester. The strongest responses were found to the mother's touch. Further differential responses were found between age groups, with third-trimester fetuses clearly differentiating between different sources of tactile stimulation, while second-trimester fetuses hardly showed differentiated responses.

It is suggested that maturational differences in both experiments are due to the fetal development of the central nervous system, and might indicate the emergence of a proprioceptive self-awareness by the 3rd trimester.

Volume 1

Chapter 1

Introduction

Fetal development is a particularly intriguing period in human development; it is the basis for being born into the world and developing into a functional human being. Every human being begins life on this planet as a zygote, a multicellular diploid eukaryote carrying 46 chromosomes, 23 from each of our parents, and will develop into an embryo, then a fetus and eventually into a human being over the course of 9 months.

These 9 months in utero are crucial for later development. Apart from genetic predispositions received from the parents, external factors influence the fetal development by altering gene expression, which determines cognitive, behavioural, psychiatric, and neurodevelopmental development, cardiovascular and metabolic functioning, with persisting effects into adulthood, or altering susceptibility to diseases later in life (Bale et al., 2010; Barker, 1998; Bergman, Sarkar, Glover, & O'Connor, 2010; Brown & Susser, 2008; Khashan et al., 2008; Rutter & O'Connor, 2004). External factors can affect and alter altering gene expression. These external factors include stress, via the HPA-axis (hypothalamic-pituitary-adrenal axis) of the mother, by environmental factors such as electricity outages and wars, shortages of food, or teratogens, such as environmental toxins (i.e. pollution), drugs (i.e. Thalidomide), maternal diseases (i.e. Rubella) (Bergman et al., 2010; Talge, Neal, & Glover, 2007). The HPA axis mechanism is a feedback mechanism including the hypothalamus, pituitary gland, and adrenal glands, which are involved in the physiological stress response and other bodily functions such as the functioning and regulation of the immune system, digestion, mood, emotions, energy expenditure and storage (De Kloet, Joëls, & Holsboer, 2005; de Kloet, Sibug, Helmerhorst, Schmidt, & Schmidt, 2005; Leonard, 2005). The hypothalamus responds to stress by releasing corticotropin-releasing factor (CRF), stimulating the anterior pituitary gland, which in turn releases ACTH (Adrenocorticotropic hormone) into the bloodstream to stimulate the release of cortisol into the bloodstream from the adrenal glands (Malenka, Nestler, & Hyman, 2009). The released cortisol in the bloodstream alters metabolism. The hypothalamus senses the increase in cortisol in the bloodstream and can adjust the required levels accordingly (Malenka et al., 2009). During pregnancy the developing fetus and the mother share her blood supply, thus the fetus will be exposed to any hormonal changes the mother undergoes, and although the placenta acts as a filter, profound changes in maternal cortisol level can have a, sometimes lasting, metabolic effect on the fetus (Ellison, 2010; Mastorakos & Ilias, 2003).

However not only do stressful events impact upon the mother and the developing fetus but their timing is also crucial (Khashan et al., 2008; Rondó et al., 2003). Severe adverse life events during the first trimester are associated with increased risk of congenital malformations, mental health disorders, including later schizophrenia (Khashan et al., 2008), whereas stressors during the second and third trimester increase the risk for premature delivery or growth retardation of the newborn (Rondó et al., 2003).

The majority of studies interested in fetal development tend to focus mainly on the developmental outcomes of difficult or stress-impacted pregnancies (Bale et al., 2010; Barker, 1998; Brown & Susser, 2008; Ellison, 2010; Rutter & O'Connor, 2004).

Only the use of ultrasound made it possible to examine fetal behaviour in detail, which allowed researchers to gain a whole new understanding of fetal development (Emory, 2010; Reissland & Hopkins, 2010). The advances of ultrasound made it possible to examine fetal development and emergence of movements over the course of gestation (de Vries, Visser, & Prechtl, 1988; 1982; 1985). This was followed by research focusing on whether the fetus is capable of responding, by movement, to external stimulation as first measured by pure tone auditory stimulation via loudspeaker of the maternal abdomen (Shahidullah et al., 1994). Earliest responses were found from 19 wGA (weeks gestational age) to a 500Hz tone. Further results indicated that low frequencies are responded to first, possibly promoting language acquisition, whereas responses to higher frequencies are to follow from the third trimester (33-

35wGA) onwards (Shahidullah et al., 1994). Further research making use of maternal ultrasound scans investigated the effects of maternal voice on the fetus, using loudspeakers (Kisilevsky & Hains, 2011; Kisilevsky et al., 2003; Krueger & Garvan, 2014). Results indicate an increase of fetal heart rate (FHR) to maternal voice and a decrease to a stranger’s voice (Kisilevsky et al., 2003). Other studies, however, indicate a decrease to maternal voice, and a voice dependence upon gestational age with younger fetuses exhibiting a declarative response to recorded maternal voice (Kisilevsky & Hains, 2011; Krueger & Garvan, 2014). A FHR deceleration to maternal voice was found from 32wGA, suggesting a neurodevelopmental maturational transitional period (Kisilevsky & Hains, 2011). Interestingly these studies present maternal voice via loudspeaker which alters the natural properties of the maternal sound. The fetus becomes familiar with the maternal voice over the course of its development as it is exposed to it every day and has unique properties. Maternal voice is not only composed of the frequency and intensity of the voice, but more importantly the vibroacoustic characteristics of the maternal voice are capable of traveling through the maternal abdomen through bone conductivity, eliciting vibrations of the diaphragm moving in synchrony to the mother’s voice (Querleu, Renard, Boutteville, & Crepin, 1989). Thus live maternal voice is a multimodal stimulus, rather than a unimodal sound, at which it is presented through a loudspeaker. More importantly, the use of a loudspeaker does not only eliminate the unique multimodal properties of maternal voice but also alters the source of the sound completely. A loudspeaker placed next to the maternal abdomen playing back a recording cannot mimic true maternal voice. Directionality, multimodality, and maternal heart rate variability are all altered, thus transforming the recorded maternal voice into a novel stimulus for the fetus. Other studies examining fetal responses to maternal recorded voice report a decrease for older fetuses (Lecanuet, Manera, & Jacquet, 2002; Voegtline, Costigan, Pater, & DiPietro, 2013), other studies found no difference between FHR to recorded maternal and stranger’s voices (Shahidullah & Hepper, 1993). Inconclusive results from the literature, therefore, are likely to be due to methodological issues. FHR does not appear to be the most reliable and stable response measurement; thus other methodological approaches need to be considered in order to examine the fetal response to external stimulation in more detail.

Only one study examined the effects of live maternal voice on the fetus, comparing it to maternal recorded and stranger's recorded voices (Hepper & Shahidullah, 2007). Findings from this study suggest that the fetus responds with a deceleration of movements to live maternal voice, whereas it responded with an increased response to both maternal and stranger's recordings. This key finding proposes that, in order to examine the true effects of maternal voice on the fetus, the maternal voice needs to be presented live, and not via loudspeakers. Unfortunately, the examination of fetal movements has so far relied on overall general movement response frequencies, instead of an objective coding system, which allows tracking individual behavioural responses to maternal voice (Shahidullah & Hepper, 1993). Previous research has examined detailed fetal movements to maternal live voice and found a deceleration in arm and head movements to maternal voice compared to a silent control and maternal touch condition (Marx & Nagy, 2015).

A part of this thesis, will therefore examine maternal live versus recorded maternal voice in comparison with a non-communicative sound and control, which will be discussed in more detail later in this chapter, will use a fine-grained fetal movement coding system to analyse the responses to both live and recorded voice, since fetal movement responses appear to be a more reliable measure then FHR responses (Shahidullah & Hepper, 1993).

In order to further examine the fetal responses to maternal voice and to overcome previous methodological difficulties with FHR measurements, this thesis is going to employ a previously piloted individual movements paradigm (Marx & Nagy, 2015) examining both second and third-trimester fetuses to ensure maturational differences in fetal development is accounted for.

In general, this research is interested in analysing how the fetus responds to external stimulation during its development, including stimuli that are potentially socially relevant such as maternal voice and touch in comparison to other environmental stimuli with no obvious social relevance. Previous research has focused on differential responses to the presentation of maternal voice versus strangers' voices (Kisilevsky & Hains, 2011; Krueger & Garvan, 2014; Lecanuet et al., 2002; Shahidullah & Hepper, 1993; Voegtline et al., 2013). The methodological issues that arose during reviewing the literature will be examined further in this thesis. A further interest of this thesis lies in fetal behavioural responses to tactile stimulation of the abdomen, which is something mothers intuitively engage in on a daily basis during pregnancy, thus another external stimulus with a possible social relevance.

This thesis will begin with examining the development of the fetal nervous system, which plays a crucial part in the fetuses' capabilities to process and responds to stimulation, followed by the development of different types of fetal movements during gestation, and finally, exploring the sensory development in the embryo and the fetus. This background information aims to give a neurodevelopmental framework to Experiments 1 and 2, regarding fetal responses to maternal voice and maternal touch.

Key processes leading to the normal development of CNS - Neural development

The development of the nervous system is a complex process. The central nervous system (CNS) is one of the earliest that begins to develop and is the last to be fully completed long after birth (Dobbing & Sands, 1973).

The earliest processes of segregation (neural induction) give rise to the neural plate from the embryo's dorsal ectoderm at approximately 14 days' post fertilisation (Ladher & Schoenwolf, 2005). The induced neural plate rolls into the neural tube 21 days' post fertilisation, this process is known as neurulation (Ladher & Schoenwolf, 2005). The neural tube will differentiate over time and will, later on, form the CNS (Ladher & Schoenwolf, 2005). The closing of the neural tube begins in the central region and continues in a zip-like fashion towards both ends (Ladher & Schoenwolf, 2005). The cranial end closes on day 24 and the posterior neural pore closes at 26 days after fertilisation (Ladher & Schoenwolf, 2005). The neural tube then will differentiate into the brain and spinal cord; the hollow portion of the neural tube will differentiate into the brain's ventricular system and the central canal of the spinal cord. Forebrain (prosencephalon), midbrain (mesencephalon), hindbrain (rhombencephalon), and spinal cord differentiate from the cranial end of the neural tube around 4 weeks after conception (Ladher & Schoenwolf, 2005). By the end of the 5wGA the prosencephalon develops into two vesicles, the diencephalon posterior (caudal forebrain) and telencephalon anterior (rostral forebrain) (see Table 1a) (Ladher & Schoenwolf, 2005).

The diencephalon will give rise to the hypothalamus and thalamus contributing to the formation of the posterior pituitary gland. The anterior pituitary gland differentiates from the oral ectoderm. The hypothalamus is a central component of neuroendocrine function controlling the anterior pituitary involved in thermoregulation, hunger, sleep, circadian rhythm, and important aspects of attachment behaviours (De Kloet et al., 2005; Leonard, 2005). Both the hypothalamus and the anterior pituitary gland are necessary for the functioning of the before mentioned HPA axis. The telencephalon gives rise to the cerebral cortex, olfactory cortex and olfactory bulbs, hippocampus, and basal ganglia, making up the largest portion – in weight and size - of the human brain (Larsen, Schoenwolf, Bleyl, & Brauer, 2009). The midbrain will differentiate from the mesencephalon, differentiating into superior colliculus, inferior colliculus, tegmentum and cerebral peduncle (Ladher & Schoenwolf, 2005).

The rhombencephalon (hindbrain) continues to differentiate into the metencephalon and myelencephalon. The metencephalon will form the cerebellum and pons, and the myelencephalon gives rise to the medulla oblongata (Larsen et al., 2009). The medulla oblongata is part of the brainstem and is responsible for respiratory, cardiac, vasomotor functions and is necessary for primary reception of auditory signals (Afifi & Bergman, 1998).

During development, the rhombencephalon is characterized by a subdivision of anatomically identifiable rhombomeres (r1-8). The rhombomeres give rise to the neural crest, which in turn form the sensory components of the cranial nerves (Darnell, 2005). Connecting sensory-motor reflex arcs are formed laterally by interneurons. Motor neurons contributing to the motor component of the cranial nerves (CN) are formed ventrally (Patestas, 2006). From specific rhombomeres (1-8) specific cranial nerves derive allowing for specific functions (sensory, special sensory, motor, and autonomic), which are crucial for the fetus to being able to perceive sensations from the environment and to respond accordingly (Patestas, 2006) By the fourth week post-conception (4wGA), all cranial nerve nuclei are present. General somatic afferent (GSA) nerves are involved in carrying general sensory information such as the perception of pressure, touch, temperature and pain from cutaneous structures such as the skin and hair as well as general proprioception, being aware of one's body position, from somatic structures such as tendons, muscles, joints of neck and head to the brain. CN's included in GSA are CN V (Trigeminal), VII (Facial), IX (Glossopharyngeal), X (Vagal). The fifth CN (Trigeminal) plays a crucial part in pressure sensation as well as muscle stretch sensation. The trigeminal nerve is part of the trigeminal system, which is crucial in the perception of tactile stimulation across the body, thermal sensation, and nociception. Nearly half of the sensory fibers of CN V are sensitive to touch and terminate in the thalamus (Patestas, 2006).

The thalamus acts as the primary site to relay sensory information, apart from olfaction, to the cortex. Sensory information, which reaches the thalamus and is not filtered out, is relayed to relevant areas in the cortex such as the somatosensory areas of the brain, i.e. primary motor cortex, primary sensory cortex, or auditory cortex where further processing of perceived stimuli takes place (Patestas, 2006).

The general somatic efferent (GSE) nerves are involved in providing general motor innervations from the brain to skeletal muscles such as extraocular muscles (III, IV, VI) and muscles in the tongue (XII) (Patestas, 2006). Nerve fibers transmit special sensory input from the ear, such as the vestibular apparatus for equilibrium and the cochlea for hearing, as well as visual information through the vestibulocochlear (VIII) and optic (II) nerve, respectively. CN VIII and II together form the special somatic afferent (SSA) (Jacobson & Rao, 2013; Patestas, 2006). The auditory branch of the CN VIII is connected to the three bony ossicles in the ear, which transduce sound waves into neural impulses in the cochlea (Jacobson & Rao, 2013; Patestas, 2006). The discussed CN's are crucial for the fetus to being able to perceive and react to external stimulation (Patestas, 2006). At around 7 wGA the brainstem begins to take over fetal movement control, which up to this point was mainly reflexive and driven by the spinal cord (Dunné et al., 2010). Until the end of pregnancy divisions of the spinal cord and brainstem will mainly be in charge of fetal motility, with cortical control increasing slowly towards the end of pregnancy (Dunné et al., 2010).

The above-mentioned neural processes are of key importance for the fetuses' sensory and motor capabilities, allowing it to perceive and respond to stimulation of the outside world.

Table 1a. Table showing the developmental progression of ectodermal differentiation of the central nervous system. Cranial nerves (CN) as mentioned above are: I Olfactory (special sensory), II Optic (special sensory), III Oculomotor (autonomic, motor), IV Trochlear (motor), V Trigeminal (sensory, motor), VI Abducens (motor), VII Facial (sensory, motor, autonomic), VIII Vestibulocochlear /Auditory (special sensory), IX Glossopharyngeal (autonomic, motor, sensory), X Vagal (sensory, motor, autonomic), XI Accessory (autonomic, motor), XII Hydroglossal (motor).

Germ Layer	Major division	Early sub-division	Later subdivision	Mature derivatives	CN association	Classification
ectoderm	outer ectoderm	epidermal ectoderm	epidermis	skin	none	non-neural
				hair		
				Nails		
				Sebaceous glands		
				Tooth enamel		
				Anterior pituitary		
		placode ectoderm	Lens placode	Lens, cornea		
			Nasal placode	Olfactory epithelium	CN I	Peripheral Nervous System
			Auditory (otic) placode	Cochlea, vestibular apparatus	CN VIII	
			Epibranchial placodes	Sensory ganglia	CN V, VII-X	
	neural crest	neural		Schwann cells	r1	
				Neuroglial cells	r2, CN V	
				Sympathetic NS	r3, CN V	
				Parasympathetic NS	r4, CN VI, VII, VIII	
		Non-neural		Facial cartilage	r5, none	
				Dentine of teeth	r6, CN IX	
				melanocytes	r7, none	
				Adrenal medula	r8, CN X, XI, XII	
	Neural tube	Prosen-cephalon	telencephalon	Cerebral cortex	none	Central nervous system
				Basal ganglia		
				hippocampus		
			diencephalon	Retina		
				Thalamus	CN II	
				Hypothalamus	none	
				Infundibulum/posterior pituitary		
				Epiphysis/pineal		
		Mesen-cephalon	mesencephalon	Superior colliculus	none	
				Inferior colliculus		
				Tegmentum		
				Cerebral peduncle		
		Rhomben-cephalon	metencephalon	Cerebellum		
				Pons (rhombomere 1)	CN IV (motor)	
			myelencephalon	Medulla (rhombomere 2-8)	CN V-VII, X-XII	
		Spinal chord	Cervical, throacic, lumbar & sacral nerves		None	

Development of Fetal Movements

Overview of neuromotor development

Stages of fetal maturation of the CNS are reflected by the fetal repertoire in the form of activities and functions which are under constant development. Thus fetal functions and activities are expanding constantly (O'Rahilly & Müller, 1999).

This chapter is going to provide insights into the most important milestones of fetal neuromotor development and will be followed by separate sections on the development of individual movements over time. It is of importance to cover the development of individual movements in order to gain an understanding of the fetal movement capabilities and possible responses which are to be expected when analysing the fetal behaviour.

The first synapses of the spinal cord are detectable at 6-7 wGA (Okado, Kakimi, & Kojima, 1979). The establishment of synaptic connections to the motor neurons leads to the display of earliest fetal motor movements also referred to as spontaneous vermicular movements (Okado & Kojima, 1984). At 7.5 wGA weeks of gestation, the first efferent-afferent circuits are present in the spinal cord which results in embryonic motor reflexive activity at 7.5 wGA (Okado, 1981). As fetal neuromotor development progresses, the fetus is capable of displaying more and more movements, building on the already established motor activity (Salihagic-Kadic, Kurjak, Medić, Andonotopo, & Azumendi, 2005). The first complex and organized movements can be seen from 8-9 wGA onwards and resulting from supraspinal influence on motor activity (de Vries et al., 1982) and are also referred to as general movements. General movements appear without amorphous movement in temporal sequences and include movements of the trunk, limbs, and head. This is a phenomenon explained by the neuron’s intrinsic capability to propagate and generate action potentials immediately following interconnection (Stafstrom, Johnston, Wehner, & Sheppard, 1980).

As the medulla oblongata matures, temporally preceding other structures of the brain stem, fetal movements become more numerous and frequent from 10 wGA (Salihagic-Kadic et al., 2005). This results in reflexive movements of the trunk, head, and limbs, alternating fetal heart rate and breathing-movements between 10-11 wGA (Joseph, 1999).

Simultaneously earliest signs of handedness can be seen by this stage, which could indicate the beginnings of brain organization (McCartney & Hepper, 1999; Shahidullah et al., 1998), and first facial movements emerge (Mulder, Visser, & Bekedam, 1987). Targeted and “goal-directed” hand movements can be observed from 13 wGA, meaning that the fetus is capable of adjusting its directional speed when approaching the face, introducing intentionality behind the movement as random movements would not be adjusted for and the movement would terminate abruptly instead of coming to a controlled hold once approaching the target. From 13-14 wGA the fetus displays isolated finger movements (Kurjak, 2003; Pooh & Ogura, 2011).

Throughout the second trimester of pregnancy, the fetal repertoire of behavioural complexity and patterns continue to expand. As the development of the subplate zones (i.e. basal and alar plate) begins, a zone for neuronal connections and transient synapses, organised fetal movement patterns emerge and fetal states start developing (15-17 wGA) (D'Elia, Pighetti, Moccia, & Santangelo, 2001; Kostović & Rakic, 1990; Natale, Nasello-Paterson, & Turliuk, 1985).

The basal plate will give rise to the motor nuclei, general somatic efferent fibers (carrying motor impulses from the brain to the skeletal muscles),

special visceral efferent’s (providing motor innervations to the muscles), and the general efferent fibers (providing impulses to the smooth and cardiac muscles and glands) (Drake, Vogl, & Mitchell, 2009). The alar plate neuroblasts give rise to the solitary nucleus involved in autonomic regulation; general visceral afferent fibres required for taste; trigeminal nerve nuclei, containing general somatic afferent column conducting sensations of touch, temperature and pain to the brain; the cochlear nucleus, related to auditory processing; and visceral nuclei, containing special somatic afferent fibres carrying information from the special senses of vision, hearing and balance; the inferior olive involved in motor control relaying information to the cerebellum; and containing the dorsal column nuclei responsible for carrying tactile and proprioceptive information from the body to the brain (D'Elia et al., 2001; Drake et al., 2009; Kostović & Rakic, 1990; Natale et al., 1985).

From 16 wGA fetal eye movements can be observed which gradually increase in frequency occurrence (Nijhuis, 2003). By 24 wGA the lower brain system, consisting of brainstem and cerebellum, matures, which is essential for the maintenance of flexor tone of the limbs (Amiel-Tison, Gosselin, & Kurjak, 2006). As the mesencephalon matures, sucking, swallowing, facial expressions, as well as eye-movements, become visible by 28 wGA (Kurjak et al., 2005).

During the third trimester of pregnancy, the CNS continues maturation, and lamination distribution and neuronal differentiation of the thalamocortical axons occur (Kostović, Judas, Rados, & Hrabac, 2002). However, the main regulator of fetal movement patterns remains the still maturing brain stem (Joseph, 1999). Between 26-28 wGA peripheral connections with the CNS appear functional (Klimach & Cooke, 1988), which continue maturation over the course of pregnancy.

At 34 wGA the basal ganglia and cerebral hemispheres emerge as part of the upper motor control system and are essential for the control of the lower brain system, the cerebellum, and brainstem, allowing for relaxation and control of the limbs (Amiel-Tison et al., 2006).

Distinct fetal behavioural states can be observed during the last week of pregnancy, and fetal heart rate and movements become more integrated with fetal eye movements (Pomeroy & Volpe, 1992; Merz & Weller, 2005). As a result of brain stem maturation, the number of general movements decreases as the complexity increases during the last 10 weeks of pregnancy (Pomeroy & Volpe, 1992; Merz & Weller, 2005). Mouth movements, swallowing, yawning and facial expressions, however, decrease during the end of the third trimester (Kurjak et al., 2005). Last but not least, it has been demonstrated that fetal to neonatal behavioural movement continuity exists, as all movements exhibited in utero are observable in neonatal life (Kurjak et al., 2004; Stanojevic et al., 2011).

First occurrences of fetal individual movements

The development of movements is important for determining the maturation of the nervous system (Hepper & Shahidullah, 2007). Obviously, other factors will also have an effect on how and when certain movements evolve, and these factors can be internal or external. Internal factors include genetics, gene mutations, errors in gene expression as well as the development of the nervous system. External factors include maternal nutrition, alcohol and drug intake, stress, toxins, radiation, environmental pollution, maternal infections and possibly other external stimulation of the fetus (Bergman et al., 2010; Talge et al., 2007).

The development of two-dimensional (2D) ultrasound allowed to begin investigate fetal movements (Arabin, Bos, Rijlaarsdam, Mohnhaupt, & van Eyck, 1996; de Vries et al., 1982; 1985; 1988; Sedgmen, McMahon, Cairns, Benzie, & Woodfield, 2006; Shahidullah et al., 1994; Shahidullah & Hepper, 1994). 2D ultrasound allows visualising the fetus on a plane to plane basis, which allows capturing the whole fetus on a cross-sectional plane. It has been a reliable tool to visualise the fetus and has thus been employed by researchers to examine the fetus movements (Campbell, 2002). Nijhuis (2003) utilised 2D ultrasound in order to gather information about different developmental stages of fetal motility. They found that factors like time of the day or when the last meal was taken also can affect fetal motility. Another important factor impacting upon which movements the fetus elicits is gestational age. This is because fetal movements and behaviour can be seen as the output of the development of the fetal central nervous system, which in part is dependent on maturation (Nijhuis, 2003).

Researchers measured and reported the noted first occurrences of different fetal movements (Table 1b). The first heartbeat can be observed between 5.5-6.5 wGA, which is followed by just discernible movements from

7.5-8.5 wGA, these just discernible movements will differentiate further as the development of the fetal CNS progresses and soon general movements of the limbs can be observed from 8-9.5 wGA (Nijhuis, 2003). Over the course of the development, the frequency of the movements increases until the point is reached where the fetus is limited in space resulting in a decrease in gross motor movements, especially during the last weeks of pregnancy (Nijhuis, 2003).

Table 1b. Table displaying first occurrences of fetal movements across gestational weeks (wGA) (bpm = beats per minute).

Fetal Activity	First occurrence	Additional information
Fetal heart activity	5.5–6.5 weeks	Varies across development 5-6wGA 100bpm, 9wGA 169bpm, 12wGA 156bpm
Just-discernible movement	7.5 - 8.5 weeks	
Startle	8.0–9.5 weeks	
General movement	8.5–9.5 weeks	Decrease sharply after 14 wGA, and again after 27 wGA (de Vries et al., 1985)
Stretch	10.5–15.5 weeks	
Rotation	10–11 weeks	
Isolated arm/leg movement	9.5–10.5 weeks	
Jaw opening	10.5–12.5 weeks	
Sucking and swallowing	12.5–14.5 weeks	Regular mouthing movements during quiet state, more powerful sucking movements during active state (Nijhuis, 2003)
Yawn	11.5–15.5 weeks	
Breathing movements	10.5–11.5 weeks	Not continuously present. Increased after glucose intake (24wGA), decreased in smokers, can be absent for 2h
Hiccups	8.5–10.5 weeks	

Eye movements	slow	16 weeks	Difficult to measure and compare to neonate, less rapid movements found in growth-retarded & hydrocephalic fetus
rapid		23 weeks	

General and Localised Movements

General movements are described as general bursts of motion involving the whole body (de Vries et al., 1985). General movements can first be observed from 7.5-8.5 wGA (Nijhuis, 2003) and continue to increase afterward. The peak time of general movements is between 10-11 wGA and after this time, motility declines from 12 wGA. Another sharp decrease can be observed from 14 wGA (Piontelli, 2010). Between 14-25 wGA (Roodenburg, Wladimiroff, van Es, & Prechtl, 1991) these movements continue at a stable rate until another rapid decrease from 27 wGA (de Vries & Hopkins, 2005). The progressive rapid decrease in general movements is most likely due to the increasing size of the fetus throughout development, which leads to a decrease of the available space in utero. The fetal growth rate is 15g/kg per day from 25g/kg to 37-39 wGA (Fowden, Coan, Angiolini, Burton, & Constancia, 2011). During the last two to three weeks of gestation, the growth rate decreases to 6g/kg per day. It is suggested that the steady increase in growth is due to tissue formation, whereas the flattened increase is due to tissue differentiation preparing the fetus for a postnatal life (Fowden et al., 2011).

Over the course of development neural changes take place, motion control shifts almost completely from spinal cord control to cerebellar, brainstem, and possibly initial cerebral cortical regulation and modulatory functions such as inhibition begin. Thus it is argued that the decrease in fetal motions during the last weeks of pregnancy is due to both spatial restrictions as well as inhibitory control (Piontelli, 2006).

During early fetal development general motions are fragmented, that is, the fetus moves, has a break, and moves again in cycles. Prior 20 wGA pauses between brief bursts of motions can last up to 13 minutes (Prechtl, 1985; 1990). As the fetus develops further motions are combined to episodes and they also last longer (3-6 min), whereas pauses are generally shorter, lasting only 4-5s by 26-27 wGA between bursts (Prechtl, 1990; Visser & Prechtl, 1988).

As the fetus matures and comes closer to term, movement pauses increase lasting up to 20 minutes by 30-32 wGA, and up to 30 minutes thereafter (de Vries et al., 1985).

Prior to 26 wGA general movements are not observed simultaneously with breathing movements, the fetus functions in an either/or modus, randomly, whereas from 26 wGA motions can be observed while short bursts of breathing movements occur (Mulder, O'Brien, Lems, Visser, & Prechtl, 1990; van Vliet, Martin, Nijhuis, & Prechtl, 1985). This might be beneficial for development, as after birth the fetus needs to be capable of breathing and moving simultaneously. Moreover, from 30 wGA the fetus is often observed to include motions such as swallowing or breathing whilst moving, again this is crucial for postnatal life and displays the advancement of neurodevelopment (Piontelli, 2015). Premature neonates are often observed to stop breathing, indicating that the last weeks in utero are crucial for being able to function properly postnatally (de Vries et al., 1985). However, this also means that preterm newborn babies are a particularly high-risk population, meaning that the stop of the breathing could be due to numerous physiological and pathological complications (de Vries et al., 1985).

General movements can be thought of as a sensorimotor “storm” during which the fetus is capable of eliciting vestibular, tactile and proprioceptive sensations simultaneously (Piontelli, 2015). By moving, the fetus is able to touch itself as well as the uterine environment, whilst developing a sense of proprioception via self-stimulation (McCartney & Hepper, 1999).

General movements are also beneficial for other reasons such as tendon, muscle, and bone formation and growth. Research investigating curarized animal fetuses found severe alterations to the skeletomuscular system as well as physical deformities when the animals reached adulthood (Moessinger, 1983; Shea, Rolfe, & Murphy, 2015). Other possible reasons for the importance of fetal movements are the prevention of adhesion to the uterine wall, as the fetus prior 20 wGA has not yet developed the stratum corneum, a thin protective layer of skin (Christianson, 1999).

Early fetal movements are solely generated within the spinal cord. By 7 wGA the encephalic trunk of the brainstem takes over the majority of spinal cord functioning regarding fetal movements. Between 10-12 wGA breathing movements and swallowing emerge, both non-spinal activities. Cortical control is minimal during this stage of development and fetal motility is primarily due to the brainstem and spinal cord control, however, over time, cortical control will increase as neurodevelopment progresses (Dunné et al., 2010). Although it was long believed that fetal movements are purely reflexive in nature, it is now believed that they are not. As cortical processing increases the reflexiveness of movements decreases and so intentionality increases (Castiello et al., 2010).

Localised movements involve segments of the body moving. The occurrence of localised movements increases during the second half of pregnancy and outnumber bursts of general movements, which decrease during the course of pregnancy. As mentioned before the decrease of general movements could in part be due to the increased inhibitory control of the CNS as well as the relative decrease in uterine space (Huang, 2009; Sillar, McLean, Fischer, & Merrywest, 2002). Localised movements last on average between 3-14s (28-34 wGA), being shorter than generalised movements (34 wGA, up to 60-90s) (de Vries et al., 1988). Furthermore, unlike general movements, localised movements can co-occur with breathing movements and swallow (de Vries et al., 1988). Localised movements have been found to be goal-directed, not necessarily implying intentionality, however, they are accurate movements of action. Such movements are like scratching the forehead, rubbing eyelids, touching the face or placenta, or moving the umbilical cord(de Vries et al., 1988). General movements, on the other hand, appear more like bursts of movements without a specific target (de Vries et al., 1988).

Unlike generalised movements, localised movements are driven by momentary fetal requirements and are targeted. Thus the difference between generalised and localised movements involves a distinction between possible relevance for maturational outcome and control of movement, respectively (Marder & Calabrese, 1996).

Head Movements

Isolated head motions begin from 9.5 wGA and are present at all stages of fetal development (Nijhuis, 1992). Head movements include lateral turning, flexion and extension. By 26 wGA head movements become more pronounced as the fetal neck has elongated over the course of development thus resulting in more flexibility and pronounced head movements due to fall of muscular tone (Isaacson, Mintz, & Crelin, 2013). Backward stretches and bending of the head are frequently observed before 28 wGA but can rarely be observed from 9.5-12.5 wGA (Nijhuis, 1992). Between 34-36 wGA head movements are mostly characterised by slight lifting followed by a sudden drop or bending (head rotations). Head rotations at the later stages of pregnancy tend to occur repeatedly (3-6 bouts) (Isaacson et al., 2013). Fetal neck muscles are not strong enough to hold the head in a position yet (Isaacson et al., 2013). A similar phenomenon can be observed in neonates, who are only capable of lifting their head momentarily (Bly & Ariz, 1994). Complete control of the head will be obtained by 6 months when the cervical muscles are developed further (Bly & Ariz, 1994). Head movements near the end of the term can be seen as preparatory movements for birth, which aid the fetus during labor to drive the body through the birth canal correctly (Cunningham, Leveno, Bloom, Spong, & Dashe, 2014). Difficulties during labor can arise if the fetal head and other body parts do not move well (Cunningham et al., 2014).

It has been hypothesised that the observed head rotations between 32-34 wGA mark the beginning of the rooting reflex, which after birth allows the neonate to reflexively turn its head towards any object stroking the mouth and cheek, which results in increased head rotations, until the object is found securing the mouth to it (Golden, 2014). This rooting reflex is crucial for the infant to find the mother's nipple in order to consume breast milk. The rooting reflex disappears in infants after 4 months of age (Golden, 2014).

However, there are other reasons for the infant to being able to perform head movements. These are important in order to visually track objects, people and other items of interest attracting the infant's gaze (Vital-Durand, Atkinson, & Braddick, 2010). Similarly, the infant is able to move its head towards pleasing sounds and away from loud, unexpected disturbing noises, which is often accompanied by twitches, startles or other movements if the sound is perceived as appealing (Muir & Clifton, 1985).

Lateral head movements are also important for the infant's survival, being able to turn the head away if respiration is accidentally occluded, for example, in the prone position (Prechtl, Fargel, Weinmann, & Bakker, 1979). Backward head flexion's, often accompanied by arching the body, practiced in utero are needed for later survival in order to signal discomfort and move away from potentially harmful stimuli, i.e. inedible food or milk, or to display discomforts such as tiredness or pain. These movements are primitive spinal movements, which are present in all mammals (Poppele & Bosco, 2003). Thus localised head motions, which are practiced in utero and do not have any communicative purpose at that point, become of communicative and expressive function in the social postnatal world.

Hand Movements

Most of the tactile exploration is via hands and hand movements. We can explore the world using our hands and manipulate objects by utilizing fine and gross motor hand and finger movements. Although fetal hands are not yet equipped with these skills, they are well-appointed with the necessary attributes necessary for touching and sensing. Due to the hands', especially the fingertips' rich innervation of sensory fibers fetuses use their hands as perceptual tools, a source of proprioceptive and tactile feedback (Sparling, Van Tol, & Chescheir, 1999). As pregnancy progresses and tactile sensitivity progresses the hands will become a fundamental tool to explore the uterine environment as well as the own body. These explorations lead to learning, orienting and even in the development of a body schema (Gallagher, 2006). Zoia et al. (2007) used a kinematic approach, analysing gathered ultrasound videos to observe directionality, smoothness of movements and deceleration/acceleration of fetal hand to mouth contact and hand to eye movements. Until 18 wGA there was no evidence for coordinated movements, reaching was characterised by poor control being inaccurate and hand trajectory was found to be jerky. By 22 wGA fetal hand movements became more clearly aimed towards the target and overall straighter, interestingly speed of movement appeared to be planned depending on size and delicacy of the target object (Zoia et al., 2007). This research reflects how fetuses learn to evolve arm control as well as primitive processes of action planning. Strikingly, fetuses altered the speed depending on the delicacy of the target, i.e. slowing down more if reaching for their eyes compared to the mouth, possibly implying the awareness of somatosensory sensitivity as well as the evidence for an internal body schema. These findings resemble results on action planning obtained from infant studies as well as children where similar kinematic changes were observed (Newman, Atkinson, & Braddick, 2001; Thelen, Corbetta, & Spencer, 1996). However, these results are contrary to results from reaching studies with newborns, which suggest that intentional and coordinated reaching is not observed until 3-4 months (Baillargeon, 1987). These differential results could be explained by the change of the environment; thus recalibration is necessary to coordinate hand to mouth movements from a viscous to the non-viscous environment. This suggests that environmental specific maturation processes might be at place, which cannot be maintained after birth and require recalibration (Zoia et al., 2007).

Touch is inseparable from proprioceptive feedback, and proprioception is relevant to object detection, thus fetal hands can be regarded as tools to aid sensory perception. From 30 wGA hand-face contacts can be observed more frequently. Towards the end of pregnancy (34-38 wGA) the fetus touches its face for prolonged periods of time for longer than 10 seconds (Myowa-Yamakoshi & Takeshita, 2006). The face is innervated by the trigeminus nerve (CN V) and its branches, making it the most sensitive area of the human body. The trigeminus (CN V) is capable of nociception, proprioception, and tactile sensations, providing a whole array of sensory feedback. Thus by touching the face, the fetus will receive a variety of stimulation. Although the face is richly innervated by the trigeminus nerve (CN V) the fetal head also has insensitive areas such as the cranium and fontanelles, which are not innervated by any nerves (Piontelli, 2010). Fontanelles are membranous, non-sensitive areas of the skull, which remain flexible for parturition, allowing flexibility for the skull during labour (Yan, Kruger, Nielsen, & Nash, 2015). Insensitive areas of the skull are not often engaged with by the fetus unlike sensitive areas of the face and skull (Piontelli, 2015).

Between 26-28 wGA fetuses are observed to increasingly touch other parts of their body, such as feet, thighs, and knees, which hardly have been engaged with before. Fetal touch occurs on both sides of the hands, possibly eliciting different sensations from a less sensitive and harder surface (Piontelli, 2010). Interestingly fetuses are rarely observed to touch insensitive body areas as thorax, abdomen, or buttocks (Piontelli, 2010). Research has shown that more than half of fetal arm movements engender mouth touches and it has also been observed that the fetus opens its mouth in anticipation to a mouth touch (Myowa-Yamakoshi & Takeshita, 2006). However, mouth opening does not necessarily need to be due to anticipation, it might also be independent or spontaneous. Further studies need yet to further investigate this issue. Infants at the age of 5 months are commonly observed to open their mouth in anticipation to touch (Rochat & Hespos, 1997). However, these acts are mainly guided by vision, whereas prenatally vision is the least used sense.

Fetuses are often said to be grasping the umbilical cord (Sparling et al., 1999), this, however, is not necessarily an intentional grasp. Towards the end of pregnancy, as the uterine environment becomes progressively more crowded, the umbilical cord will be physically nearer to the fetus. During the end of gestation, the palmar grasping reflex develops (34-36 wGA) resulting in the reflexive prolonged grasp of the umbilical cord (Milani-Comparetti & Gidoni, 1967). The palmar grasp reflex belongs to the group of primitive reflexes and occurs when an object strokes the palm resulting in a closure of the hand grasping the object. Just like many other primitive reflexes, however, this also disappears over the course of development (Milani-Comparetti & Gidoni, 1967). Prior to the development of the palmar grasp reflex, fetal grasping of the umbilical cord is much shorter (4-6s) compared to later stages in development (Humphrey, 1970; Sparling et al., 1999). Although the fetus develops capabilities of grasping and interacting with its body during gestation, it does not develop manipulative capabilities, these will form at later stages during infancy.

Leg and Feet Movements

In humans, hands are the primary tools for manipulating objects in the outside world. Feet and legs on the other hand ultimately serving bipedal locomotion and allow us to walk, stand, jump, run and hop. The fetus uses feet primarily for movement. First, isolated leg movements can be observed from 7-10 weeks after conception (de Vries et al., 1982). By 14wGA limb movements become coordinated (Moore, Bergman, Anderson, & Medley, 2016). From about 26 wGA movements are performed with increasing skill, variety and speed, however as spatial restrictions increase, legs are predominantly flexed rather than extended (de Vries et al., 1982). As the fetus grows and the contact with uterine membranes increases fetuses are often observed to perform stepping movements from 24-26wGA which are currently regarded as the beginning of the walking reflex, which is observable in infants (Stocche & Funayama, 2006). The walking reflex is among the primitive reflexes in the newborns, which is already practiced in the uterine environment prior to birth. The intrauterine fluid, with its resistance, aids the fetus to prepare these movements, which later on after birth will be performed in a more complex manner, requiring more strength and coordination without the support of the amniotic environment (Stocche & Funayama, 2006). Premature newborns, however, do not display many of these primitive movements, thus it can be argued that fetal motor development is greatly facilitated by the intrauterine unique environment (Stocche & Funayama, 2006). As with all other fetal movements, leg movements are essential for skeletal and bone formation. The importance of leg movements can be illustrated, for example, by restricting the legs severely, which results in deformed limbs such as club feet (Christianson, 1999). This condition can occur naturally due to prolonged oligohydramnios (a deficiency of amniotic fluid) during pregnancy (Christianson, 1999).

Fetal Breathing Movements

Fetal lungs are not involved in oxygenation or other forms of gas exchange in utero. Oxygenation and exchange of nutrients with the environment, in utero, occurs through the umbilical cord and placenta. Fetal breathing can be observed across species that rely on aerial respiration (Bonar, Blumenfield, & Fenning, 1938; Rosenfeld, 1936). In the human fetus, breathing can first be observed from 10.5-11.5 wGA (Nijhuis, 2003). The prevalence of fetal breathing movements is 2% from 10 wGA, increasing throughout pregnancy up to 12% of the time at 20-22 wGA, and at 30-32 wGA 35% (Koos, 2008).

Fetal breathing movements are different from adult breathing movements. Fetal breathing movements consist primarily of downward movements of the diaphragm, whilst simultaneously the thorax performs a minor inward movement (2-5mm) and the abdomen at the level of the navel moves outward (Boddy & Dawes, 1975). Newborns' breathing movements are primarily due to abdominal and diaphragmatic muscular activity, not including thoracic movements like the fetus. Differences in fetal breathing movements from breathing movements in extra-uterine life can be accounted for by a truncated shaped thorax with almost horizontally positioned ribs, as compared to curved like in children or adults, and a shorter sternum (Isaacson et al., 2013). The adult mainly relies on intercostal muscles, whereas the fetus relies on the diaphragm, abdominal wall muscles, and glottal adductor muscles. Prenatal breathing is not continuous and consists of short bursts of movements. Breathing movements are regulated via the brainstem until later during gestation (Boddy & Dawes, 1975; Natale et al., 1985).

Interestingly, fetal breathing does not occur simultaneously with other fetal limb movements until 25-26 wGA (Lau, Sheena, Shulman, & Schanler, 1997). Even after that breathing movement are seldom seen in conjunction with other movements, however, they do occur during later stages of pregnancy.

Breathing and swallowing are regarded as two separate movements, both occurring independently as general movements stop co-occurring up until 26-28 wGA. After about 29-30 wGA the fetus is beginning to fine-tune breathing and swallowing (Kuipers, Maertzdorf, De Jong, Hanson, & Blanco, 1994). This is essential for successful feeding after birth to prevent choking. Premature neonates often show difficulties with this coordination, resulting in the suspension of breathing during feeding and resulting in life-threatening apnoea (Piontelli, 2010). Thus severely premature neonates are often tube-fed (Piontelli, 2010). The capability to coordinate the two emerges between 32-35 wGA in utero and is vital for life after birth (Lau et al., 1997).

Fetal breathing serves the function of lung extension and aids development of the alveolar air sacs. It also plays an important role in the development of neural regulation and respiratory muscles. The lung is filled with pulmonary fluid aiding lung growth in conjunction with breathing movements leading to tissue expansion. Structural maturation of the lung and growth is due to the interplay of many different factors and is the result from a complex interaction of a variety of factors (Jost & Policard, 1948; Policard, 1938).

The rate of breathing bursts changes throughout pregnancy, as does the number of breathing movements that are increasing throughout gestation until 38 wGA when reaching a plateau. Breathing movements in the early stages of pregnancy are characterised by short bursts lasting less than 10 s. Medium bursts (10-30s) increase, longer episodes (>30 s) however remain rare. Short as well as medium bursts have been linked to lung development and fetal growth long bursts have not.

Mouthing movements: Swallowing and Sucking

Swallowing requires 26 muscles and 6 cranial nerves, most importantly the vagal and glossopharyngeal (CN X, IX) nerves (Lau et al., 1997). Swallowing is characterised by an intake of a substance, in the case of the fetus, it is amniotic fluid, which passes from the mouth to the stomach without entering the lungs (Lau et al., 1997). Fetuses before 15-16 wGA appear to simply open their mouths, appearing to draw in amniotic fluid like fish. From 20 wGA mouth opening and closing occurs in short sequence drawing amniotic fluid into the oral cavity, passing down the pharynx without involving any tongue movements. However, from 27-28 wGA tongue movements begin to differentiate and to grow in complexity. For example, cupping of the tongue can be observed when drawing in amniotic fluid, this is seen as proper sucking compared to simple sucking, which occurs prior tongue engagement. Simple occasional swallowing is first observed between 10-12 wGA, increases in occurrence until it can be noted during most examinations between 19-20 wGA. The mouth opens prior each swallow; complete closure of the mouth is not necessary. From 26 wGA less wide mouth openings and barely noticeable lip-puckering can be observed from 26 wGA, and sealing of the mouth between swallows is noted at 30-32 wGA. Again closure of the lips during sucking has important implications for feeding in postnatal life (Piontelli, 2010). Over time swallowing bursts increase from 4-6s at 14 wGA, over 6-10s between 15-16 wGA to 6-14s at 30-34 wGA, as can be seen in the neonate. Most of the time swallowing occurs as a sole event, not accompanied by other fetal movements.

From 36-38 wGA fetal sucking can be observed. By creating a partial vacuum, the liquid is drawn into the mouth through coordinated movements of the lips, tongue, and mouth, involving cheek muscles, which provide stability during sucking (Avery & ElNesr, 2001; Achiron et al., 1997). Sucking is controlled by and is closely linked to the maturation of the brainstem; hence it only occurs in near-term fetuses.

Fetal sucking and swallowing have been shown to play an important role in gut maturation (Lotgering & Wallenburg, 1986) and amniotic fluid volume regulation (Couture, Ferran, Saguintaah, & Veyrac, 2008). Furthermore, studies suggest that swallowing of amniotic fluid accounts for 15-20% of total body protein deposition (van Woerden et al., 1988). Therefore, sucking and swallowing aid fetal development in utero and prepare the fetus for survival during postnatal life.

Yawning

Although the reasons for yawning are still not clearly understood, we can note that yawning is universal across vertebrae species through the lifespan. First yawns can be observed between 10-12 wGA (de Vries et al., 1985) and then remains stable until term (Reissland, Mason, & Francis, 2012). Yawns are described as a prolonged opening of the mouth (3-6s on average) followed by a quick closure, often accompanied by a retroflexion of the head and occasionally lifting of the arms especially during early stages of pregnancy. Compared to other mouth movements yawns are usually non-repetitive (de Vries et al., 1982). During yawns, the rib cage is stretched more than during breathing motions, thus it is hypothesised that yawns contribute against the formation of pulmonary webs, that is, yawning facilitates the proper development of the airways preventing tracheal and bronchial webs. Formation of pulmonary webs would result in infant death at birth, as the newborn would not be capable of breathing (Roberts, 1999). It has been observed that yawns generally do not occur in combination with other movements, rather they tend to follow other movements (Piontelli, 2015). It is suggested that during general movements the rib cage gets distorted and yawns act against these, placing the lung and diaphragm back to its normal state. The fetal lung contains a limited amount of collagen fibers and elastin, which is needed for natural elastic recoil (Jost & Policard, 1948), thus fetuses yawn often. Another possible function of yawning could be expanding the trachea and other breathing related organs allowing them to pursue normal growth (Bartlett, Gazzaniga, & Geraghty, 1973; Duggan & Kavanagh, 2005). Even adults are encouraged to yawn and to take deep breaths following surgery to prevent pulmonary and tracheal collapse (Bartlett et al., 1973; Duggan & Kavanagh, 2005). Thus it can be concluded that yawn has more than one vital functions pre- and postnatally.

Hiccups

Fetal hiccups can be observed from 9 GA weeks. They are observed frequently peaking between 10-12 wGA, decreasing steadily until 24-26 wGA. Hiccups are accompanied by contractions of the diaphragm and are the most relevant diaphragmatic motion until 24-26 wGA (de Vries et al., 1985; Pillai & James, 1990). Hiccups start declining as fetal breathing movements begin to become more frequent. Although hiccups occur while the fetus is moving, they do not occur simultaneously during breathing or swallowing. Decreases in hiccups when fetal breathing emerges might support respiratory functions, aiding diaphragmatic expansion and growth even after birth (Piontelli, 2015). The diaphragm is essential for initial postnatal breathing as the rib cage is yet to develop from a box-like shape to an adult shape. Therefore, newborns rely primarily on the diaphragm as well as abdominal muscles for respiration. Until the rib cage has developed properly breathing is not supported by the thorax.

It has been observed that preterm newborns hiccup more frequently than term newborns do (Brouillette, Thach, Abu-Osba, & Wilson, 1980). Repeated hiccupping in preterm babies is also related to gastrointestinal reflux (Brouillette et al., 1980), however, later in infancy, it is suggested that hiccups prevent such reflux (Brouillette et al., 1980). Although hiccups can be observed prenatally as well as postnatally, their primary function remains relatively unclear, perhaps it has multiple functions.

Facial expressions and fetal facial movements and tongue protrusion

It is important to point out that the reference to facial expressions in the following section does not equal facial emotions/basic emotional expressions. Facial expressions have been of interest since Aristotle (1913) and earliest empirical work addressing the universality of facial expression dates back to Darwin’s work *The expression of emotions in man and animals* (1872). Darwin was the first to claim that facial expressions are universal amongst different ethnic groups and are biological rather than learned and acquired throughout life, thus he proposed that they are a product of evolution. Darwin (1872/1965) observed young infants and discovered the presence of facial expressions in them and suggested that facial expressions are a basic hardwired function of survival. Since Darwin's (1872/1965) observations, research in the line of facial expressions has been of interest again.

The first major quantitative research on the topic of facial expressions has been done by Ekman and Friesen (1978) who created a facial action coding system (FACS), describing facial movements as they are visible on the skin. They also proposed a possible correspondence between the Action Units and the basic emotions (Ekman, Friesen, & Hager, 1978). Oster (2006) studied babies' facial expressions and devised the Baby FACS, outlining the differences in facial movements between infants and adults The Baby FACS has been adapted to take developing changes from baby to infant into account and intensity of facial expressions to the caregiver (Oster, 2006). Oster (2006) suggests that infant facial expressions along with other communicative behaviours are crucial for normal development and infant survival and describes these as ontogenetic adaptations. Another line of research questions these taxonomies due to the limited amount of included signals, other nonverbal communication signals, and that the claimed expressions do not all need to have communicational intent but might also indicate an inner state (Fernandez-Dols, Sanchez, & Carrera, 1997).

When discussing prenatal expressions, the term fetal facial motions might be more appropriate than expressions as it is impossible to determine whether the fetus intends to express anything with its facial gestalt. Expressions or expression labels the facial gestalt with the implication of a form of social communication and the presence of others to perceive these actions, thus some researchers prefer to refer to them as facial motions (Reissland, Mason, Lincoln, & Francis, 2011). It is possible that the fetus is preparing for a life in a social world and needs to, in a way, practice facial gestalts to being able to perform them when born.

In the womb the fetus is never fully awake; its chemical environment keeps it in a sedative state or asleep (Mellor, Diesch, Gunn, & Bennet, 2005). The feto-placental unit produces an array of endogenous inhibiting factors which inhibits the fetus to experience full wakefulness (Mellor et al., 2005). This, however, does not mean to say that the fetus remains in an unconscious state throughout pregnancy. Fetuses are capable of responding to external stimulation by increasing or decreasing heart rate or movements (Kisilevsky, Muir, & Low, 1992; Shahidullah et al., 1994), however, it is rather difficult to show that the expressed facial movements are directly related to changes in internal emotional states. A study exploring fetal facial pain/distress gestalt showed that facial expression increases in complexity between 24-36 wGA until it increasingly resembles that of a sleeping neonate (Reissland, Francis, & Mason, 2013). The maturation of facial gestalts matures over the course of pregnancy and by 36-38 wGA the fetus's repertoire matches that of a sleeping neonate (Reissland et al., 2013).

Facial expressions can be considered pre-programmed phenomena since the fetus is incapable of learning facial expressions through imitation. Facial expressions mature over the course of pregnancy and prepare the neonate for the external environment. The connection between experiencing a particular emotion and expressing the concordant facial expression in utero do not need to be related as such. However especially during later stages of fetal development facial expressions cannot be regarded as meaningless as a fetus in distress is unlikely to be observed smiling (Piontelli, 2015). The repertoire of facial motions is continuously more refined as time progresses until it matches that of a neonate (Reissland et al., 2011; 2013). Once born the baby is exposed to the social environment it can learn through observation and refine preprogrammed facial expressions.

Another related facial motion, which is often observed in the neonate is tongue protrusion (Anisfeld, 1996; Meltzoff & Moore, 1977; 1989; Nagy & Molnar, 2004). At 26 wGA full protrusion and lateral tongue movements can be observed (de Vries et al., 1982). Following full tongue protrusions, fetuses can be observed exploring their environment by the tongue, licking body parts such as hands, placenta, and umbilical cord (30 wGA) (Piontelli, 2015). Neonates are said to explore their environment with their tongues, thereby it is reasonable to assume that the roots of this exploratory behaviour can already be observed in utero (Ruff, 1984).

Brain development and sensorimotor intentionality and conscious experience

Earliest movements have been found from 7-8 wGA (de Vries et al., 1982) and the onset of early sensorimotor control and prospectivity measured develops quickly as it has been observed at 14 wGA using kinematic movement analysis observing twin fetuses' movements (Castiello et al., 2010). At 7 wGA the cervical spinal cord nuclei are swiftly developing axodendritic synapses between motor and interneurons, followed by afferent fibers and interneurons. The brain's 'special visceral nuclei' are formed and innervated by the integrative emotional systems (Gloor, Olivier, Quesney, Andermann, & Horowitz, 1982). The onset of motor movements at 7 wGA and their confirmed prospective control and sensory-motor control at 14 wGA suggest more primitive neural motor systems at work, instead of a cortically mediated sensory learning mechanism as the CNS is still premature in development (Castiello et al., 2010). Frist controlled isolated movements are observed at 8 wGA (Okado, 1980). Adequate appendicular skeletal muscles with motor and sensory nervous connectivity to the brainstem nuclei and spinal column for simple proprioceptive motor control is present by 8wGA (Okado, 1980). Whereas forebrain and neocortex are yet to organize (Larroche, 1981) and thalamocortical projections are yet to mature (Hevner, 2000).

It has been proposed that corticospinal projections do not reach the cervical spinal cord until 24 wGA (Eyre, Miller, Clowry, Conway, & Watts, 2000), implying that the established connectivity to limb musculature between brain stem, spinal column, and midbrain must be responsible for early prospective controlled movements of the fetal limbs.

The ancient brain structures - brainstem, spinal cord, and diencephalon - have recently been proposed to have the capacity for decision making, learning and memory, and integration of information allowing a new perspective on the functionality of the brain stem, recognizing the capacity of higher cortical functions and as a quintessence of conscious agency (Bechara, Damasio, & Damasio, 2003; Merker, 2007; Northoff & Panksepp, 2008; Panksepp & Northoff, 2009; Winn, 2012).

The brainstem contains functional characteristics for implementing a primary form of consciousness, a perspective and embodied experience of the agent, also referred to as ‘acting with knowing’. The brain stem preserves proprioceptive and tactile information (Marx et al., 2005), the midbrain is involved in the processing of receiving receptor projections of ears, eyes, and nose incoming from exteroceptive sensory information, monitors visceral organ function focusing on the body’s vital wellbeing and physiological needs. Hindbrain cortices are involved in the relay of sensorimotor control needed for coordination of voluntary skeletomuscular control of movements. Thus a ‘brain stem selection triangle’ has been proposed between target selection, action selection, and motivational ranking based on the bodies vital needs for primary conscious experience (Merker, 2007).

Early studies investigating conscious control of action in patients with either surgically removed cortices or born without a cerebral cortex revealed no impairments of conscious experience (Merker, 2007; Penfield & Jasper, 1954; Shewmon, Holmes, & Byrne, 1999; Solms & Panksepp, 2012). Observations of hydranencephalic or anencephalic children, children not possessing cerebral cortices but with intact brainstems, are conscious and capable of experiencing a rich emotional and social life, with coordinated movements of their limbs for both mobility and communication (Merker, 2007; Penfield & Jasper, 1954; Shewmon et al., 1999; Solms & Panksepp, 2012).

The development of sensorimotor intentionally appears to be rooted in the midbrain and upper brainstem regions, which have been identified as the ‘core central control system’ responsible for goal-orientated control and action selection, proposing that the conscious experience is to incorporate sensory information for directing and selecting appropriate motor actions (Merker, 2007; Northoff & Panksepp, 2008; Vandekerckhove & Panksepp, 2011). In order to respond to environmental affordances integration of proprioceptive, viseroceptive, and exteroceptive domains is needed to direct agency mediating body motor coordination and endogenous motives for action. The midbrain tectum, more so the superior colliculus, and its nuclei extending to the hypothalamus, along with the midbrain reticular formation, periaqueductal grey, ventral tegmentum, ventral thalamus, and substantia nigra are all responsible for integrating, developing, and processing spatiotemporal frames for body movements. These brain regions along with distinct 'locomotor centers' represent basic mechanisms for navigation purposes (Merker, 2007).

The cerebral cortex should therefore not be regarded as the primary focus of goal-directed body movements, but more so as an additional development to improve the primary conscious experience and function of prospective interaction with the world (Merker, 2007). Throughout the development of the cortex, it refines its cognitive capacities and allows the agent to process stimuli on a higher level by forming a conceptual understanding, plans, and beliefs of the external world. Together with the limbic structures, the cortex is capable of expanding action plans which draw on previous experiences of the agent (Delafield-Butt & Gangopadhyay, 2013).

As the cortex matures it advances in development allowing for the increased integration of stimuli involving different brain regions and processes (Vandekerckhove & Panksepp, 2011). Thus over the course of development cortical maturation enables a shift from a primary conscious experience to a conscious experience involving cortical abstractions, sophisticated planning and control, and complex evaluations.

Early simple actions such as moving the arm or legs are simple goal-directed actions, which over time as the cortex matures, increases integration, and is capable of processing more information simultaneously, the sensory knowledge and consequent effects of simple actions expands and allows for the development of more complex actions throughout development (Corbetta &

Snapp-Childs, 2009). Serial organisation of single actions allows for complex actions to emerge. Serial motor organisation is driven by improving cognitive processes, memory, knowledge of the world, and previous experience of actions and their effects, which allow for an increasing capacity of fine motor control, first driven by basic and later by more complex sensorimotor intentions as the individual matures (Corbetta & Fagard, 2017; Corbetta, Thelen, & Johnson, 2000; Thelen et al., 1996).

At birth the newborn is capable of pre-reach, coordinating whole body movements to an object of interest (Hofsten, 1984). Although movements after birth are simple, they are goal-directed, and prospective control increases over the course of development until the infant is capable of performing complex action units (Hofsten, 1984; Van der Meer, Van der Weel, & Lee, 1995). The infant's intelligence is therefore vastly dependent upon its anticipation of consequences of actions or serially organised actions, which mature over time so that one simple action units can develop into complex action units with greater distal purpose as sensorimotor intelligence increases (Vandekerckhove & Panksepp, 2011). First, decision-making is primarily brainstem mediated, which, later on, is driven by the executive cortex responsible for higher-order and conscious reasoning of distally-orientated prospective action plans (Maricich et al., 2009; Vandekerckhove & Panksepp, 2011; Winn, 2012).

In summary, the core of primary sensorimotor intentionally integration is found in the upper brain stem, which senses, controls, and senses the body's musculoskeletal actions. As previously discussed, the primary form of embodied intentionality is enrooted in the integrative body motor activity which is first observed during early ontogenesis. Through acting, moving of the body, the development of 'acting with knowing' (Marx et al., 2005), or sensorimotor intentionality, develops throughout gestation and continues to do so in the following years as the infant continues to develop its capabilities of complex motor actions.

Can fetuses be social, too?

It is argued that newborns are born into this world, ready for social interactions (Kugiumutzakis, 1999; Trevarthen, 1993b; Bard, 2007; Nagy & Molnar, 2004). Even hours after birth newborns are prepared to interact socially, for example, by means of imitation of facial gestures (Meltzoff & Moore, 1983; 1989). Therefore, the question arises whether an ability for social interactions is present before birth.

It would be rather illusive to assume that primarily the event of labour will turn the fetus into a social being, especially when rates of normal delivery (35.5% in 2011-12; spontaneous births 58.7% 2013, Scotland) are decreasing as caesarean sections are increasing (28.5% in 2012-13, Scotland) (Information Services Division, 2014) yet no matter how we are brought into this world, we are all capable to interact in a socially immediately after birth (Kugiumutzakis, 1999; Trevarthen, 1993b; Bard, 2007; Nagy & Molnar, 2004). Once the fetus is born it will be exposed to a new environment with a whole range of visual and tactile information, which was not present prior to birth. However, it could be argued that based on the previously outlined sensory and neurodevelopmental processes, the fetus is most likely to be predisposed for social interactions, especially near term.

It is feasible to assume that the fetus must, at some point during its development, develop the capabilities, at least to some extent, for social perception and responsivity.

Important evidence to support this argument comes from studies with twin fetuses, as these studies enable us to observe possible social interactions within the womb. Castiello et al. (2010) have investigated whether twin fetuses present a predisposition towards social interaction prenatally and whether their other-directed movements were intentional or not.

Kinematic profiles of twin fetuses were observed and the results showed that between 14-18 wGA self-directed movements decreased and movements towards the co-twin increased, whereas no difference was found in the proportion of movements towards the uterine wall (Castiello et al., 2010). The decrease of self-directed movements corresponds with data from previous research and is possibly related to a decrease in intrauterine space (D'Elia et al., 2001; de Vries et al., 1988; Sparling et al., 1999). Increases of other-directed movements are also consistent with previous findings, repeatedly reporting that contact between twins increases over time (Arabin et al., 1996; Hata et al., 1998; Piontelli et al., 1997). Kinematic analysis on whether these movements reflect motor-planning or accidental contacts revealed increased movement duration and deceleration time during twin-touch compared to self-touch and touching the uterine environment (Castiello et al., 2010). These results, therefore, suggest that from the beginning of 14 wGA executed movements towards the co-twin reflected motor planning, thus they are more likely to be intentional than accidental. Given this evidence, it is feasible to argue that it is possible for the fetuses to react differentially to social stimuli prior to birth. However, evidence for possible social responsivity in fetuses needs to be established.

Sensory Abilities

The investigation of fetal sensations proves rather difficult due to accessibility issues related to its environmental circumstances. The observation of some of the fetal responses is, however, somewhat easier, such as heart rate changes or more recently, behavioural responses to stimulation visualised by the means of ultrasound techniques. The understanding of the observed movements, however, carries its own difficulties since it is challenging to discriminate between a voluntary, reactive and a spontaneous movement.

Additionally, we are unable to know how and in what way exactly the fetus experiences external stimulation. Previous research revealed the importance of innate reflex circuits of the brain stem, which are capable of controlling many responses such as heart rate changes, startles, facial motions, or sucking rates (Piontelli, 2015). Despite the definite insights gained into fetal development, the examination of human fetal sensations would involve invasive stimulation possibly harming the fetus and therefore remains unfeasible and inaccessible. The closest researchers have come to examine human fetuses' reactions to sensations is by the means of vibroacoustic stimulation (Kisilevsky et al., 1992), and reported that fetuses displayed a FHR deceleration from 26-28 wGA, followed by an acceleration of 10 bpm from 29 wGA. Movement reactions were observed in most subjects from 29 wGA, suggesting that maturation to vibroacoustic response begins at 26wGA and continues by 32wGA. The direct examination of fetal sensations, however, cannot be visualised the same way as fetal heart rate and movements can be.

Despite our poor understanding of the fetal sensational experience research has made its advances in unraveling the development of the senses. Both tactile and auditory development will be discussed with respect to this thesis in the following sections.

Touch

How does touch work?

The skin is the largest sensory organ in the human body transmitting sensory perceptions to the CNS. The skin is innervated by a combination of sensory neuron subtypes such as thermoreceptors, registering temperature; proprioceptors, conveying itch; nociceptors, sensing painful stimuli; and low-threshold mechanoreceptors, sensing non-painful mechanical stimuli such as touch. These low-threshold mechanoreceptors and mechanosensory end organs are responsible for our experience of touch (Johnson, 2001).

Touch is more than just the capability of sensing and recognising an object touching the skin, it is also crucial for object manipulation, for experiencing the textures of the food we eat, for sexual pleasure and procreation, for social interactions and communication, and for maternal nursing (Morrison, Löken, & Olausson, 2010).

Touch development in the fetus

The skin serves as a barrier to the body and the external world. It serves many functions, especially its molecular and cellular interface is crucial for its functional role in perception and neurobehaviour (Hoath, 2004). Experiments by Hooker and Humphrey showed that the human embryo reacts to localised tactile stimulation of the skin from 8-9 weeks GA, evoking a reflexive movement response involving action and inhibition (Hooker, 1960; Humphrey, 1970).

By 23-25 wGA the premature fetus is capable of surviving in the extra-uterine environment, with help of medical intervention (Ambalavanan et al., 2012), which is at the time of epidermal barrier formation, the skin structure crucial for postnatal transition and survival (Hardman, Ferguson, Byrne, & Moore, 1999; Madison, 2003). Without a functional epidermis, the newborn would not be capable of surviving.

During the first stage of ontogenesis, the ectoderm lateral differentiates to the neural plate to develop the epidermis (Hall, 2008). Mesenchyme and neural crest cells will later on form the dermis. During ontogenesis ectoderm and mesenchyme align next to each other to allow cross-talk required for membrane and skin appendage formation such as nails, sweat glands, and hair.

During the second stage, histogenesis, a variety of morphological changes occur in the presumptive skin of the fetus. These are stratification, appendage involution, and differentiation of the epidermis as well as the mesenchymal subdivision of hypodermis and dermis, and vascular neogenesis (Hall, 2008). During the third stage, the stage of maturation, the skin develops fully for the organism to survive in the extra-uterine environment. The skin develops the capabilities to provide thermoregulatory capacity, barrier function, and surface tensile strength (Johnson, 2001).

Origin of Epidermis – Surface ectoderm forms epidermis

The epidermis is the outer layer of the skin. Its primary function is to form a protective barrier between the outside and the inner organs. Its barrier role provides protection from environmental pathogens, UV radiation, and regulation of body temperature and water loss (Madison, 2003). The fully developed epidermis is composed of five layers, which are the following from top to bottom: the stratum corneum, stratum lucidum, stratum granulosum, stratum spinosum and the stratum basale forms the lowest layer of the epidermis touching upon the dermis (Larsen et al., 2009).

The three primary embryonic germ layers, endoderm, mesoderm, and ectoderm are created during the third week after fertilisation (Larsen et al., 2009). Following gastrulation, the ectoderm is subdivided into neuroectoderm and presumptive epidermis. The epidermis will then differentiate further into distinct regional domains such as mammary skin, scalp skin, and palmoplantar skin. During neurulation, the embryonic ectoderm infolds to become the neural tube and subsequently spinal cord and brain. At this stage, the presumptive epidermis is loosely connected to a single cell layer (Grubauer, Feingold, Harris, & Elias, 1989). By 8 wGA most regions of the body are covered by the surface ectoderm, consisting of superficial periderm cells and basal cells (Elias, Goerke, & Friend, 1977). Basal cells make up the basal layer, the bottom layer of the epidermis, which is separated from the dermis via laminin, fibronectin, and collagens. The periderm sheds gradually into the amniotic fluid and is shed completely by 21 wGA (Larsen et al., 2009). During 11 wGA the basal layer proliferates producing an intermediate layer deep to the periderm (Larsen et al., 2009). This intermediate layer will, later on, produce the mature epidermis (Larsen et al., 2009). At this stage, the basal layer is also referred to as the stratum germinativum or germinative layer. Its stem cells will continue restoring the epidermis throughout life (Alonso & Fuchs, 2003). Keratinocytes are found in the intermediate layer of the epidermis. Keratinocytes are proteins producing keratin, and its function is to protect the epithelial cells from stress or damage (Owens & Lane, 2003). By the 5^{th} month of fetal development as the periderm is shed, the intermediate layer is transformed into three layers of keratinocytes: outer stratum corneum, middle stratum granulosum, and inner stratum spinosum (Byrne, Tainsky, & Fuchs, 1994). Layers of the epidermis follow a maturational series. The stratum germinativum constantly produces keratinocytes which differentiate as they move outward towards the stratum corneum, and are finally shed from the surface of the skin as they become progressively flattened. The differentiated keratinocytes reaching the body surface are dead, flattened, and enucleated, which are then sloughed and continually replaced by inner outward moving cells from underlying cell layers (Matsui & Amagai, 2015). Amongst the different skin layers, the stratum germinativum contains the only dividing cells of the epidermis due to their keratin filaments which are connected to desmosomes. Desmosomes are cell to cell membrane junctions providing an impervious, tight structure resistant to infection and water loss and uptake, and distributing the force applied to the epidermis evenly (Peltonen, Raiko, & Peltonen, 2010).

Over the course of development the layers continue developing and by 22-24 wGA the epidermis is made up of 4-5 layers (Kalia, Nonato, Lund, & Guy, 1998). During the third trimester, the formation of supplementary layers continues until the formation of the epidermal barrier is complete at 30-34wGA (Evans & Rutter, 2004; Kalia et al., 1998). Once the epidermal barrier is formed the fetal skin has the same barrier functionality adults have.

Apart from keratinocytes the epidermis contains other cells such as Langerhans cells, melanocytes, and Merkel cells (Byrne et al., 1994; Dale, Holbrook, Kimball, Hoff, & Sun, 1985; Madison, 2003; Moll, Moll, & Franke, 1986; Peltonen et al., 2010). Melanocytes are pigment cells which differentiate from the neural crest cells migrating to the developing dermis in the 6th week of development (Hashimoto, 1972). By the 10th wGA melanocytes are associated with the development of hair follicles, adding pigmentation to the hairs. Other functions of melanocytes are the protection of solar radiation. Langerhans cells are the immune cells of the skin (Granstein & Luger, 2009). Their primary functions are immune surveillance of the skin against microorganisms and functioning in contact sensitivity of the skin, such as allergic reactions. They arise in the bone marrow and migrate to the epidermis by 7 wGA (Granstein & Luger, 2009; Matsui & Amagai, 2015).

Merkel cells originate from epidermal stem cells during fetal development (Bardot et al., 2013; Morrison, Miesegaes, Lumpkin, & Maricich, 2009; Perdigoto, Bardot, Valdes, Santoriello, & Ezhkova, 2014; Van Keymeulen et al., 2009; Woo et al., 2014) and start emerging between 8-12 wGA (Moll et al., 1986). Merkel cells contain keratin and together with keratinocytes, they form desmosomes. Desmosomes are important in the morphogenesis of fetal tissues and cell differentiation (Peltonen et al., 2010).

Origin of the Dermis - Mesoderm Forms Dermis

The dermis is the lower layer of the main two layers making up the human skin. The dermis is composed of blood and lymph vessels, hair follicles, sweat and sebum glands and nerve fibers. The main functions of the dermis are cushioning the body from strain and stress, providing elasticity to the skin, perception of tactile stimulation, temperature, itch and pain (Venus, Waterman, & McNab, 2011). Below the dermis lies the hypodermis, which contains a protective layer of fat insulating the body from loss of heat and cushioning the internal organs from external pressure. The fat in the dermis is also used as an energy supply for the body (Elias et al., 1977).

The dermis is a tissue with the triple embryonic origin (Larsen et al., 2009). The majority of the tissue originates from the mesoderm with parts of it deriving from dermatomal divisions of the somites. The dermis of the head, however, is derived from the ectoderm.

The outer layer of the dermis proliferates forming the dermal papillae which protrude into the epidermis during the third month of development (Larsen et al., 2009). The dermal papillae protrude into the epidermal ridges. This region of the dermis is also referred to as papillary layer and the thicker underlying layer consisting of irregular connective tissue is referred to as the reticular layer. During the second and third trimester, the dermis differentiates into its definitive form. The dermal papillae produce the pattern of external grooves and ridges of the skin, which varies across the body. During 11-12 wGA the first ridges appear on palmar and plantar surfaces (Babler, 1991). By the 5th month of gestation, all bodily grooves and ridges are established (Babler, 1991).

The nerve fibers in the upper portion of the dermis close to the surface and epidermis are Merkel cells and Meissner's corpuscles (McGlone & Reilly, 2010; Merkel, 1875; Perdigoto et al., 2014; Zimmerman, Bai, & Ginty, 2014). Other nerve fibers responsible for tactile perception such as Pacinian corpuscles and Ruffini cells lie deep in the dermis (Johnson, 2001; McGlone & Reilly, 2010; Zimmerman et al., 2014). It is important that the necessary nerve fibers and receptors are developed and functioning so that the fetus is capable of experiencing tactile sensations (McGlone & Reilly, 2010; McGlone, Wessberg, & Olausson, 2014; Patestas, 2006; White, Widdowson, Woodard, & Dickerson, 1991). This includes all forms of tactile sensations, self-stimulated touch, a touch of the uterine environment, and external abdominally administered touch such as, for example, the mother's touch. Furthermore, properly developed skin, which is a functional organ aiding thermogenesis and a protective layer for the organism to keep out harmful stimulants, allows not just the mature baby but also the premature newborn to survive in the external world (Madison, 2003; Saper, 2002).

The make-up of the Skin

The third component of the skin, next to the epidermis and the dermis, with their integrated touch sensors, is the surface of the skin. The human skin is comprised of both hairy and non-hairy skin. Non-hairy skin is also referred to as glabrous skin, which is predominantly found on the lips, hands, and feet of the human body (Olausson, Wessberg, Morrison, McGlone, & Vallbo, 2010). These glabrous skin areas are richly innervated by sensory neurons adapting it to correctly recognise objects and in turn provide feedback to the CNS which allows for proper grip control, reaching, and locomotion mediation. The glabrous skin has a higher spatial accuracy compared to hairy skin despite its increased thickness of the epidermal layer (McGlone & Reilly, 2010). Hairy skin, however, is more associated with affective touch responses, meaning touch, which elicits an emotional response. The association of pleasant properties of touch could be provided through the activation of unmyelinated, slow-conducting, and low threshold C-tactile (CT) afferents (Olausson et al., 2010). CT afferents are unique to hairy skin i.e. the face (Nordin, 1990) and arm (Vallbo, Olausson, Wessberg, & Norrsell, 1993), compared to the glabrous skin (Olausson et al., 2010).

Touch Sensors

In order to understand the complexity of the touch sensation better, we need to take a closer look at the skins' diverse range of touch sensors. There are four types of touch sensors (Aβ) in the glabrous skin: Meissner's corpuscles, Merkel disk receptors, Pacinian corpuscles, and Ruffini endings (Biswas, Manivannan, & Srinivasan, 2014a; 2014b; Maricich et al., 2009; McGlone & Reilly, 2010). Each of these receptors is specialised to different types of tactile stimulation.

Meissner's corpuscles are capable of detecting light touch and low-frequency vibrations between 10-50Hz and are essential for grip control. They are comprised of fast adapting units which are most sensitive to brief stimulation and deformation of the skin, rather than constant stimulation, and play an important role in discriminative and exploratory touch as well as the recognition of textures. Meissner's corpuscles are located shallowly in the dermis just below the epidermis and are most densely distributed in the fingertips (Ackerley, Saar, McGlone, & Backlund Wasling, 2014b).

Merkel disk receptors are responsible to recognise edges, form, and texture of objects and were first discovered in 1875 by Merkel as 'Tastzellen' – 'touch cells' (Merkel, 1875). The receptors respond to persistent stimulation and are located in the stratum basale, the bottom layer of the epidermis, with connecting nerve endings in the dermis.

Pacinian corpuscles respond to pressure and high-frequency vibration (Biswas, Manivannan, & Srinivasan, 2014b). Pacinian cells are most sensitive to sudden stimulation, especially vibrations and adapt rapidly (Biswas, Manivannan, & Srinivasan, 2014a). The main role of Pacinian cells is to detect surface textures, applied pressure, and perceive sensations through tools. They are located deep in the dermis from where they are connected to dendrites of sensory neurons transmit the mechanical information to the spinal cord and CNS.

Ruffini endings or *Bulbous corpuscles* are slowly adapting mechanoreceptors sensitive to skin stretching and contribute to the kinesthetic sense and control of finger movement and positioning. They are located deep in the dermis (Johnson, 2001).

The electrical impulses perceived by touch sensors are transmitted to the spinal cord via dendrites from where the electronic impulse is transmitted to the brain's sensorimotor cortex of the parietal lobe for further processing. These four types of mechanosensory afferents (Aβ) primarily play part in the dexterity of object recognition and goal-directed manipulation of objects we touch with our hands and fingers (Johnson, 2001; McGlone, Vallbo, & Olausson, 2007).

Further cutaneous sensors include *free nerve endings* in the dermis relaying sensory information to the brain. There are a variety of free nerve endings such as thermoreceptors (hot and cold nerve endings), responsible for the perception of temperature; nociceptors, responsible for the perception of pain; tickle receptors, and itchy receptors. The same sensory neurons exist in hairy skin, however, hairy skin is also innervated by additional touch sensors which are lacking in the glabrous skin (Nagi & Mahns, 2013). These include CT afferents and hair follicle units. *C-tactile (CT) afferents* are unmyelinated low-threshold mechanoreceptors found in hairy skin and they respond predominantly to slow stroking and a light touch of the skin (Nagi & Mahns, 2013). Response sensitivity to deformation, however, is just as sensitive as most Aβ fibers (Vallbo, Olausson, & Wessberg, 1999). CTs have been found to be relevant in the processing of pleasant touch stimuli relevant to a social context (Olausson et al., 2010). The density of CTs in hairy skin, such as the forearm, has been estimated to be roughly the same as Aβ units (Vallbo et al., 1999), becomes scarcer towards distal parts of the extremities, such as the legs (Löken, Wessberg, Morrison, McGlone, & Olausson, 2009), and appears to be lacking in glabrous skin (Nagi & Mahns, 2013; Nordin, 1990).

In order for the fetus to experience tactile sensations all the tactile afferents need to be developed, connected, and functioning.

Adaptation

Adaptation refers to the sustained response to stationary skin deformation. Broadly speaking the human touch afferents can be divided into two types: slow conducting unmyelinated afferents (CTs) (about 1 ms^{-1}) and fast conducting myelinated afferents (Aβ) (around 50 m/s). However, the Aβ fibers can be divided further into fast adapting and slower adapting afferents. The CT system is also referred to as the slow tactile system, and as previously mentioned is important for the processing of affective touch. Thus the human touch system is also referred to as a dual touch system (Toft, Fugleholm, & Schmalbruch, 1988).

As for Aβ fibers Pacini, Meissner and other hair follicle units respond quickly to dynamic stimulation but lack all sensitivity during steady skin deformation. Merkel and Ruffini cells, however, are capable of continuous discharge of signals over a longer period of time while slowly decreasing impulse rate and adapting over time. CTs, on the other hand, differ from Aβ afferents. CTs response to stimulation is immediate with a strong burst of impulses which rapidly decreases to zero within 5s following the initial burst, despite continuous stimulation (Vallbo et al., 1999). Hence CTs adaptation response characteristic is intermediate compared to other Aβ units (slowly adapting units continue firing during constant stimulation, whereas fast adapting units solely respond under changing skin). When stimulated again briefly following initial stimulation, CT response is much lower than previously, as it can take minutes for full recovery of CT depolarisation (Iggo, 1960; Iggo & Kornhuber, 1977). This implies that CTs are likely to be designed to be most responsive to initial touch rather than consecutive stimuli, allowing us to quickly recognise friendly touch, which might have had an evolutionary advantage. The functional mechanisms and advantages of the delayed response to succeeding stimulation are yet to be explored (Vallbo, Loken, & Wessberg, 2016).

From skin to Brain - Cortical processing of tactile stimulation

In order for the fetus to experience tactile stimulation, the before mentioned touch afferents need to be successfully connected to its related brain areas to allow for processing of the stimulus. Different brain areas and cross-modal, intermodal, and interconnected networks are responsible for the processing of tactile stimulation (Calvert, Spence, & Stein, 2004). In order to examine which areas are responsible brain responses to tactile stimulation were monitored using functional magnetic resonance imaging (fMRI) (Olausson et al., 2002). Soft brush stroking of the hairy skin leads to the activation of the somatosensory cortex (S1 and S2) and insular cortex, especially the contralateral insular cortex (Olausson et al., 2002). The somatosensory cortex receives input from Aβ fibers and plays an important role in the processing of discriminative touch. The somatosensory cortex is responsible for the processing of locality and integration of tactile stimulation.

The insular cortex is considered a gateway from the sensory systems to the brains emotional systems situated in the frontal lobes, making it a region of interest in respect to affective mechanisms (Augustine, 1996; Craig, 2008). Sensory neuropathological patients lacking Aβ afferents show no activation in the somatosensory cortex when stimulated, but show activation of the posterior insular areas (Olausson et al., 2002). It has therefore been suggested that the responding CT afferents project excitatory potentials to the insular cortex for emotion-related processing.

Although the contribution of Aβ fibers in relation to emotional processing is yet to be fully explored, evidence that Aβ afferents underpin the sensation of pleasant touch stimuli exists (Krämer et al., 2007). Stimulation of the palm was perceived as pleasant, despite the lack of CT afferents), and fMRI responses indicated activation of the insular afferents of the orbitofrontal cortex, which play an important role in complex emotional processing (Rolls et al., 2003). However overall, tactile stimulation has generally found to be rated most pleasant on the hairy skin compared to glabrous skin, although Aβ stimulation was also rated as pleasant, yet significantly less so (McGlone et al., 2012). The pleasant perception of Aβ stimulation could arguably be dependent on top-down contextual factors, using different cortical pathways compared to CT stimulation.

Affective Processing of Tactile Stimulation

Tactile stimulation plays an important role in everyday life. The tactile system allows us to perceive and act upon spatially and temporally-variant skin deformations. It allows us to perceive stimuli and their directionality across the skin and to engage with objects by the means of discriminative touch. In combination with other sensory systems such as hearing and vision, touch is essential for the guidance of motor activities since the sensory modalities operate in cross-modal, intermodal, and interconnected networks ensuring a multisensory experience of the environment (Calvert et al., 2004). Sensory The fetus displays guided planned movements which are likely to be shaped and guided, just like the adult's movements (Jansson, 1983), by the tactile feedback it receives from its environment (Zoia et al., 2007).

Responsible for the tactile actions are fast-conducting Aβ afferents (Biswas, Manivannan, & Srinivasan, 2014a; 2014b; Maricich et al., 2009; McGlone et al., 2012). CT afferents, on the other hand, have a much slower processing and adaptation speed, as well as decreased range of ideal stimulation speed making them unsuitable for discriminative touch. CT afferents have been shown to respond best to light stroking of hairy skin, which is related to social touch (Löken et al., 2009; Olausson et al., 2010; Vallbo et al., 1999; 1993), as the same tactile properties are present in affiliative tactile interactions between individuals (Gallace & Spence, 2010; Vallbo et al., 1999). Due to the similarities of CT afferents preferred stimulation and socially relevant tactile stimulation the “social touch hypothesis” has been proposed (Olausson et al., 2010). Slow, caressing stimulation of hairy skin occurs most often during encounters between mates, parents and their offspring and other relatives, siblings, friends, and other close associates. It is, therefore, feasible to hypothesise that affective touch is a special form of touch characterised by its social context and subjective interpretation rather than its sensory-discriminative function. Thus affective touch appears to draw on more than the qualitative and functional information perceived by Aβ afferents. The processing of social touch requires processing of both, central and peripheral central nervous system suggesting the need for a different processing pathway as for discriminative touch. CT afferents have been found to be involved in peripheral pathway processing of tactile stimulation, allowing for further affective processing of tactile stimulation (McGlone et al., 2012) such as close body contact. Pleasant touch was found to activate regions of the orbitofrontal cortex and anterior cingulate cortex more so than it activated the somatosensory cortex, which is usually activated by non-affective, neutral, touch (Rolls et al., 2003). Neutral touch, on the other hand, tends to stimulate the somatosensory cortex, including parts of the mid-insula. Studies by Rolls (2003) support the notion that the brain differentiates between different types of touch, and that emotional relevance is processed centrally in the frontal regions of the brain (McGlone et al., 2012; Rolls et al., 2003). Hence it is hypothesised that the CT system provides behavioural and emotional responses in skin-to-skin contact, supporting the “affective touch hypothesis” (Olausson et al., 2010). Ideal firing frequency of CT afferents is achieved with a slow-moving touch across the skin, which has been correlated with ratings of pleasantness (Löken, Evert, & Wessberg, 2011). More so, stimulation of CT afferents has been shown to activate the posterior insular cortex (Cole et al., 2008; Olausson et al., 2002), which is relevant to affective processing of stimuli (Craig, 2011).

Despite the lack of CT afferents and increased epidermal thickness of the glabrous skin, it has been shown that the palms are capable of perceiving pleasantness and a range of affective sensations (Ackerley, Carlsson, Wester, Olausson, & Backlund Wasling, 2014a; Löken et al., 2011). In fact, it has been found (Ackerley, Carlsson, Wester, Olausson, & Backlund Wasling, 2014a) that touch pleasantness is perceived in similar means across the whole body, likely depending on memory and previous experiences rather than CT density. This suggests that CT afferents aid processing of affective touch in the periphery; however, the experience of affective touch is determined by an array of other factors, such as emotional factors i.e. positive affect, comfort, and arousal can account for a more pleasurable tactile experience regardless. However, despite emotional factors, stimulating hairy skin evokes a stronger emotional content, more so when touched by another person compared to self-touch (Ackerley, Saar, McGlone, & Backlund Wasling, 2014b). The fetus can perceive both self-touch and touch, externally induced and transmitted via the touch of the maternal abdomen, by another person such as the mother. The mother uses touch to comfort the baby and engage with the fetus by touching and stroking her abdomen. The administered touch can be perceived by the fetus to which it responds with an increase in movements (Marx & Nagy, 2015). It is possible that the externally administered tactile stimulation is pleasant to the fetus and aids the formation of a bond between the mother and the child.

Other evidence for the role of CTs in affective touch processing, stems from subjects with sensory neuropathology, patients lacking Aβ fibers but possessing CT afferents. Patients lacking Aβ fibers are capable of perceiving the pleasantness of slow stroking on the forearm of the skin (Cole et al., 2008; Olausson et al., 2002). Stimulus perception, however, was vague and rather weak, patients are lacking proprioception thus are unable to tell where exactly they have been stimulated, and sometimes report no stimulation at all. When the same stimulus was applied to patients' glabrous skin of the palms, these patients failed to identify touch completely providing further evidence for the lack of CT afferents in glabrous skin. CT related processing appears to take place below a conscious level and is proposed to have autonomic consequences (Cole et al., 2008).

Thus CTs do play an important role in affective processing however the pleasantness of the touch stands in combination with higher-order emotional influences, previous experiences or cultural differences. Most studies investigating touch have focused on sensory aspects of discriminative touch. Dimensions of emotional and social aspects of touch have, thus far, received little attention (Olausson et al., 2010). It is proposed that CT afferents have a preference for signaling affective and emotional aspects of touch, whereas the glabrous skin provides more discriminative and exploratory information (Ackerley, Saar, McGlone, & Backlund Wasling, 2014b). With regard to the pleasantness of touch in the glabrous skin, psychophysical studies suggest that glabrous skin contains afferents which share properties of CTs, which might be responsible for the perception of pleasant touch in the glabrous skin (Nagi & Mahns, 2013) despite the lack of CTs. When the fetus is stimulated through the abdominal wall it is most likely stimulated on non-plantar surfaces such as the forearm, head, legs. These areas are richly innervated by CTs, as well as Aβ fibers, which are related to affective, unconscious, higher order processing of touch (Cole et al., 2008). Stimulation of Aβ fibers allows the fetus to perceive the type of touch administered, the pressure, vibrations, and direction of the touch experience, whereas stimulation of CTs could aid the affective processing of the touch stimulus. Thus the fetus may be capable of forming early positive experiences of comfort with the sensation of touch. Lastly kangarooing of premature newborns was shown to improve development (Feldman, Weller, Sirota, & Eidelman, 2002b) and it might be possible that tactile interaction with the fetus through the maternal abdomen could potentially have beneficial effects for the fetus, too.

Auditory Development

Auditory Information from the external environment moves through the abdominal and uterine walls and reaches the fetus where the information is processed by the fetal auditory system. Thus it has been proposed that a possible channel for potential early social interaction is the auditory channel (DeCasper & Fifer, 1980; DeCasper, Lecanuet, & Busnel, 1994; Gottlieb, 1985;

Lecanuet & Schaal, 1996; Lickliter & Virkar, 1989; Spence & DeCasper, 1987). The auditory capabilities begin to develop from about 10 wGA, and although earliest responses to pure tone stimuli can be found from 19 wGA, most fetuses seem responsive from about 26 wGA, making hearing the last sense to emerge during development (Shahidullah et al., 1994).

Previous research is well aware of the neonatal receptiveness to sound presumably based on their in-utero experience. Newborns are capable to recognise their mother's voice and prefer to listen to their mother's voice compared to those of the strangers when given the option to choose (DeCasper & Fifer, 1980). Newborns also prefer their native language, due to the previous exposure in utero (Moon, Cooper, & Fifer, 1993).

The Structure of the Auditory System

The ear is comprised of the external, middle and inner ear. The visible part of the ear is called *pinna* and is composed of cartilage covered by skin. The external ear is connected to the middle ear via the external auditory canal, which connects to the *tympanic membrane* (eardrum) (Drake et al., 2009). Sound travels through the external auditory canal where it causes the *tympanic membrane* and attached *ossicles*, three tiny bones (*malleus, incus, and stapes*), of the middle ear to vibrate. Vibrations are transmitted to the inner ear, through the *vestibule* to the *cochlea*. Within the *cochlea* rests the *organ of Corti*, a receptor organ, which transduces auditory signals into electrical nerve impulses via hair cells (*stereocilia*), which are attached to the *basilar membrane* (Drake et al., 2009). Physical movements of the *stereocilia* are responsible for the creation of electrical impulses which are transmitted via the spiral ganglion and relay nuclei in the midbrain and pons to the auditory cortex of the temporal lobe (Graven & Browne, 2008; Pujol, Pujol, & Lavigne-Rebillard, 1992).

Development of the auditory system

Structural parts of the cochlea and middle ear are well developed from 15 wGA and are anatomically functional from 20 weeks (Lavigne-Rebillard &

Pujol, 1987; Pujol & Lavigne-Rebillard, 1985). By 25-29 wGA the auditory system is functional as ganglion cells of the cochlea's spiral nucleus have successfully connected inner hair cells to the brainstem and temporal lobe (Pujol et al., 1992). Earliest responses to external sounds were found at 16 wGA from isolated fetuses, whereas all fetuses display changes in autonomic functioning, such as changes in heart rate, blood pressure, movements, oxygenation and others, to the presentation of an auditory stimuli (Shahidullah et al., 1994; Volpe, Morris, Philbin, & Bose, 2000). Neural connections to the temporal lobe continue to develop until 28-30 wGA (Graven & Browne, 2008). This triggers the development of tonotopic columns in the auditory cortex, which is needed to recognize, receive, and react to sounds such as language, music, and other environmentally relevant sounds (Graven & Browne, 2008). The two most important units responsible for the auditory processing are the cochlea and the auditory cortex, necessary for receiving and processing auditory stimulation, respectively.

Sound waves are transduced into electrical impulses via the vibrations of hair cells in the *cochlea*. Development of the *cochlea* begins around 10 to 12 wGA (Pujol & Lavigne-Rebillard, 1985). Hair cells are connected to synapses, which transmit sound impulses from the ear to the auditory nerve. Development of the hair cells begins at the base of the cochlea and proceeds outwards. The inner hair cells, on the other hand, begin development from 11 wGA and complete development by 15 wGA (Hall, 2000). The inner hair cells are responsible for transducing sound waves into electrical impulses. The outer hair cells are the last to complete development at 22 wGA (Pujol & Lavigne-Rebillard, 1985) and are essential for normal auditory sensitivity and frequency resolution (Hall, 2000).

Both efferent and afferent auditory cranial nerves (VIII) are synapsed with hair cells. One afferent neuron leading to the spiral ganglion innervates the inner and another the other hair cells. Efferent neurons projecting from the brainstem are also connected with either inner or outer hair cells. From the lateral olivary nuclei emerges the lateral efferent system, traveling through the inner spiral bundle, and terminating on the afferent auditory dendrites, which are synapsed with the inner hair cells. Projecting to both ears is the medial system, originating from the trapezoid body in the ventro-medio nuclei region, which connects to the outer hair cells. It has been proposed that the medial system precedes maturation of the lateral efferent system, which is related to the later maturation of the outer hair cells (Gil-Loyzaga & Pujol, 1988). The most prevalent function of the outer hair cells resides in receiving feedback from the brainstem and nuclei in the pons (Hall, 2000).

Depending on the frequency and intensity of the incoming sound the tympanic membrane (eardrum) will vibrate accordingly. This vibration is transmitted to the fluid chamber of the cochlea via the oval window (Pujol et al., 1992). The created waves are responsible for the disposition of the basal membrane beneath the hair cells, which leads to excitation of the hair cells (Pujol et al., 1992). Depending on the sound frequency (pitch) the location of the cochlea’s rise changes. The membrane’s rise depends on the sound intensity, with higher intensities leading to more stimulation and increased firing. Each hair cell has an individual firing frequency allowing for a varied sound experience (Jankovic-Raznatovic et al., 2014). Tuning of hair cell frequencies occurs between 28 wGA and continues in the early years of infant life (Graven & Browne, 2008).

Impulses from the hair cells are passed on to the auditory nerve and from there continue traveling to the *ipsilateral cochlear nuclei* in the *medulla oblongata* of the hindbrain (Fettiplace & Hackney, 2006). Fibers from the auditory nerve are connected to the *lateral* and *medial superior olives* allowing for bilateral information processing of the auditory stimulus. Bilateral processing allows the auditory signal from one ear to be processed by both hemispheres as soon as it appears. Furthermore, the *medial superior olives* respond to arrival time differences of the auditory stimulus, whereas the *lateral superior olives* respond to amplitude differences in sound. Input from the *superior olives* is projected ascend to the *inferior colliculus* (tectum) in the *pons* through the *lateral lemniscus* (Moore & Linthicum, 2007). Impulses from *inferior colliculus* fibers ascend to the *medial geniculate nucleus* of the *thalamus* where auditory information is initially processed and projected to the primary auditory cortex in the temporal lobe for further processing.

The auditory system, unlike other sensory systems, requires auditory stimulation during the last 12 weeks of fetal development in order for hair cells to develop properly. Stimulation will aid the fine-tuning of the hair cells, beginning with the fine tuning of lower frequencies moving over to high frequencies over the course of the development (Graven & Browne, 2008). All of these processes allow the fetus to hear its external environment throughout its development, hearing and responding to the mothers' voice, music, and other environmentally relevant sounds (Moon & Fifer, 2000). Although the fetal auditory experience does not equal the auditory experience of an adult, the fetus is capable of successfully familiarising itself with its surrounding sounds throughout maturation (Bench, 1968; Busnel, 1979; Busnel, Lecanuet, & Granier-Deferre, 1992; Peiper, 1925; Vince, Armitage, Baldwin, Toner, & Moore, 1982; Vince, Billing, Baldwin, Toner, & Weller, 1985). Moreover, even an incomplete auditory system is functional enough for the fetus to respond to simple auditory stimuli from early on, as the earliest responses to pure tone stimuli have been found to be occurring from 19 wGA (Shahidullah & Hepper, 1994).

It is important to note that the fetus resides in an aquatic uterine (amniotic fluid) environment, which alters the way the sounds transmit to the fetus. The mode of fetal hearing does not involve the participation of outer and middle ear of the fetus, but, as has been discovered through analysing fetal sheep, head vibrations are effectively transmitting uterine sound stimuli to the cochlear (Gerhardt et al., 1996).

Studying Fetal responses to sound

The functioning of the fetal auditory system may only be studied using indirect non-invasive observations of behavioural responses utilising methods such as ultrasound. Stimuli reaching the fetus in utero need to pass through the abdominal wall, uterus and amniotic fluid, all altering the fetal sound experience. Thus the external environment is perceived flannelly, protecting the fetus from disturbing sounds. Intrauterine sounds and sounds from the mother's internally generated noises, i.e. cardiovascular, respiratory, and general movements, and intestinal activity (Armitage, Baldwin, & Vince, 1980; Gerhardt, Abrams, & Oliver, 1990; Querleu, Renard, Versyp, Paris-Delrue, & Crèpin, 1988), are constantly present, forming a background "noise". The auditory stimuli reaching the fetus are therefore shaped and altered by the fluids and tissues before reaching the fetal ear (Vince et al., 1982; 1985). Background "noise" levels have been determined to reach levels up to 90dB in utero. The maternal abdomen is regarded as a low-pass filter rejecting high-frequency energy at a rate of approximately 6dB/octave (Gerhardt et al., 1990). This means that it is perceived as if for example, in the case of musical stimulation, the bass register is turned up whilst the treble is reduced.

Apart from the direct auditory pathway of sound transmission, bone conduction also plays a major part in the fetal hearing experience. Apart from studies with sheep, where microphones have been placed inside the mothers' abdomen to examine fetal sound perception (Armitage et al., 1980; Gerhardt, 1989; Gerhardt et al., 1996; Gerhardt & Abrams, 1996; Vince et al., 1982), human studies have examined divers in order to gather evidence for the importance of bone conduction in adults auditory sound experience (Hollien & Feinstein, 1975). Researchers have compared divers' abilities to hear underwater and have found that bone conduction was the most effective in transmitting underwater sound energy (Hollien & Feinstein, 1975). Bone conductivity also plays a major role in the fetal perception of sound. Gerhardt et al. (1996) examined the effectiveness of outer and middle ear and bone conduction in an experiment using fetal sheep in utero in response to airborne sounds. Their findings determined that stimuli reached the inner ear more effectively with bone conduction. This finding is concordant with results from human underwater studies (Gerhardt et al., 1996; Hollien & Feinstein, 1975). It can be argued that bone conductivity has an advantage to the fetus to hear its mother, as maternal voice can travel internally. This includes voice and the resulting vibrations and thus the fetus can become familiar with her voice much before birth. This argument is further supported with studies with newborns as it has been shown that newborns are capable of distinguishing between stranger's voices and the maternal voice just hours after birth (DeCasper & Fifer, 1980).

The earliest fetal responses to auditory stimulation have been found at 24 wGA (Birnholz & Benacerraf, 1983; Crade & Lovett, 1988) when the hearing mechanism is already functional. Research by Hepper and Shahidullah (1994) examined perceived intensity and frequency of, using pure tones, in utero and discovered that the fetal range is more limited when compared to those of the human adults. In their study, out of 450 fetuses, only one demonstrated a movement response at 19 wGA to a 500 Hz tone. However, by 27 wGA 96% of fetuses were responsive to tones between 100 and 500 Hz, but not to tones at 1000 or 3000 Hz. Responsivity to stimuli between 1000 and 3000 Hz starts between 29 and 31 wGA. Only at 33 wGA when 100% of fetuses responded to 1000 Hz and to the 3000 Hz stimuli. Over the course of development fetuses' ability to process certain frequency ranges widens. It was concluded that the fetal auditory development becomes more sensitive from 19 to 37 wGA and responses advance closer to the adult's audibility (20 to 20000 Hz frequency) near-term (Hepper & Shahidullah, 1994). Moreover, fetuses first respond to the lower frequencies of the adult auditory range (500 Hz), and this response gradually extends to higher frequencies over the course of development (Hepper & Shahidullah, 1994). Also, younger fetuses require a higher intensity stimulus to elicit a response, which also declines over the course of gestation as hearing capabilities become more sensitive. These changes reflect, amongst other factors, the progressing development of the cochlea, especially the completion and innervation of outer hair cells, turning the basal membrane from a passive to an active transducer of acoustic stimuli (Hepper & Shahidullah, 1994)

It needs to be noted that as before mentioned, the uterine environment alters the externally applied stimulus frequencies, thus the externally measured frequencies do not necessarily correspond to the perceived stimuli frequencies in utero. However, this does not influence the progression of fetal auditory responsiveness, only the relationship between particular onsets of frequencies. Querleu et al. (1988) examined attenuation of auditory stimuli by the maternal abdomen during the final weeks of pregnancy and found that the following values need to be subtracted in order to achieve accurate sound frequencies in utero: 2 dBA at 100 Hz and 250 Hz, 14 dBA at 500 Hz, 20 dBA at 1000 Hz, and 24 dBA at 3000 Hz, respectively. A change of -10 dB means the presented stimuli is perceived half as loud, -20 dB ¼ as loud and so forth (Querleu et al., 1988).

Further studies have investigated the effects of maternal sound on the fetus, exploring overall fetal movement responses (Hata, Kanenishi, & Sasaki, 2010; Hepper & Shahidullah, 1994; Shahidullah et al., 2007). Only a few studies, however, investigated the effects of maternal voice on isolated fetal movements (Marx & Nagy, 2015).

Previous studies explored the effects of maternal recorded voice vs strangers recorded voice and maternal recorded voice vs maternal live voice utilising 2D ultrasound (Hepper, Scott, & Shahidullah, 1993). Fetuses (36 wGA) were minimally exposed to the stimulus prior to testing, a loudspeaker was placed on the maternal abdomen above the fetuses' head and recordings were played back. Unfortunately, the study did not disclose the intensity of the presented stimulus. However, researchers made sure that there was a 120 sec long baseline where the fetus did not move, prior to the stimulation (Hepper et al., 1993). No differences in response to maternal versus strangers' recordings were observed in general fetal movements. However, when comparing maternal live voice (spontaneous speech) to a tape recording of her voice, fetuses displayed a decrease in general movements to maternal voice in situ (Hepper et al., 1993). It could be argued that the fetus perceived the mother's recording as a novel stimulus, just like they perceive the voice of a stranger in recordings, whereas maternal live voice was perceived as a familiar stimulus, having a calming effect on the fetus. It needs to be pointed out that only overall movements were analysed thus the exact localised movement changes remain unclear since they were measured but not analysed (Hepper et al., 1993). Newborns at 2-4 days of age were found to be able to discriminate between recorded mothers and strangers voice, presented both as motherese and spontaneous speech, and they displayed differential responses in their movements (Hepper et al., 1993). The largest decrease in movements was noted in response to maternal live voice, suggesting that it was the most familiar stimulus. Hepper et al. (1993) did code for the neonatal head, arm, and leg movements, however, results were not discussed, and an overall motion response was calculated instead.

This behavioural approach is now commonly used when examining newborns behaviour and based on the above described methodological issues regarding previous literature, it would be a preferable approach in examining fetal behavioural responses to external stimulation (Marx & Nagy, 2015).

Other studies examining fetal responsiveness have focused on fetal heart rate (FHR) changes to sound presentation (Granier-Deferre, Bassereau, Ribeiro, Jacquet, & DeCasper, 2011; Kisilevsky et al., 1992; Kisilevsky & Hains, 2010; 2011; Kisilevsky et al., 2012; Sandman, 2010). Two studies have tested FHR reactions to strangers' recorded voice, to a passage which was read aloud by the mother daily from 33-37 wGA when presented with the same passage read by a stranger via tape recording at 37 wGA, FHR decelerated (DeCasper et al., 1994; Krueger, Holditch-Davis, Quint, & DeCasper, 2004). When presented with a novel passage by a stranger, similarly, from a tape recording, fetuses displayed an increase in FHR. These findings stand in contrast to Kisilevsky and Hains' (2011) findings of an immediate FHR deceleration to maternal voice, prior 32 wGA, and acceleration in older fetuses over 32 wGA. A maturational transition in FHR responses was suggested at 32 weeks.

Studies comparing FHR changes after a long exposure of the stimulus prior to testing (daily, for 2-6 weeks) and presenting the fetus with the recorded passage either spoken by the mother or a stranger report a FHR acceleration to maternal voice and a deceleration to strangers' voice (Krueger et al., 2004). Only one study examined both FHR and movement responses and proposed the likelihood of a similar response, where an increase in FHR is related to an increase in fetal movements followed by a subsequent decrease (Shahidullah et al., 2007). If the mother's voice is a familiar stimulus to the fetus it would be reasonable to expect the fetus to display a decrease in movement and FHR compared to the voice of a stranger that should be a novel stimulus to the fetus

(Shahidullah et al., 2007) thus it is suggested that fetuses would move less to live maternal voice compared to a recording (Hepper et al., 1993; Jacquet et al., 2009; Kisilevsky et al., 2003). Krueger and Gravan (2014) reported a small FHR acceleration to recorded maternal voice. It is possible that the fetal response depends on the type of exposure, maturation, and stimulus presentation (Krueger & Garvan, 2014).

Results from studies, however, remained inconclusive and focus primarily on motherese, since all studies either require mothers to read a children’s story or nursery rhyme aloud instead of using spontaneous speech, which is arguably the most common external and socially relevant auditory stimulus the fetus is exposed to, every day.

Marx & Nagy (2015) asked pregnant women to read a children's story aloud to their fetuses, and measured fetuses’ movements using a 4D ultrasound recording and frame-by-frame analysis of twenty different movements including arm, head, and mouth movements and different tactile target areas such as body self-touch, face touch, and touching of the uterine wall. The results indicated a decrease in arm and head movements during story reading suggesting either a possible behavioural orienting or a calming effect on the fetus (Marx & Nagy, 2015).

Overall these earlier studies suggest that the fetus is capable of forming some memory of externally occurring sounds especially of the most prominent auditory stimulus, the mother’s voice. This becomes more apparent when looking at the experiment by DeCasper and Fifer (1980), who showed that newborns prefer the mother’s voice over the stranger’s just hours after birth. Therefore, it is feasible to assume that some form of memory formation to auditory stimuli must occur prenatally. Knowing when the fetus is able to perceive and process information to external stimuli would allow us to gain insight into the onset of auditory processing and higher cortical processing (DeCasper & Fifer, 1980).

In summary, intrauterine auditory development potentially enables human fetuses to differentiate and learn auditory stimuli with potential social significance from the environment.

The main aim of the thesis is to examine fetal behavioural responses to stimuli in two modalities, the auditory and the tactile. Two experiments will address these aims, separately addressing these modalities in Experiment 1 and 2, respectively.

The aim of Experiment 1: Can the fetus differentiate between different auditory stimuli?

Although our previous experiment examined fetal behavioural responses to maternal voice using direct maternal speech as opposed to voice recording, the results raised further questions about fetal perception of the mother's voice (Marx & Nagy, 2015), namely if the mother's voice an unique stimulus over other auditory stimuli.

Additionally, as argued above, the storytelling condition in the above-cited experiment might have altered the mother's voice compared to her natural speaking voice, resulting in perhaps 'motherese'. Most of the time the fetus is exposed to naturally occurring maternal voice instead of motherese, therefore, it could be argued that the fetus has familiarised itself, or is familiarising itself with naturally maternal voice over the course of pregnancy but not to motherese. Motherese or infant-directed speech (IDS) is a different kind of speech compared to adult-directed speech (ADS) (Blaauw, 1994; Hamdan, Mahfoud, Sibai, & Seoud, 2009; Saint-Georges, Chetouani, Cassel, & Apicella, 2013) and presumably elicits different reactions from not only the infant but even from the fetus.

The three main characteristics of IDS include alteration of (1) intonation such as a higher overall pitch, (2) alteration of constructions, grammar and words, and (3) include a set of specific lexical items specific to IDS (Ferguson, 1964). IDS carries many other valuable cues and information for the infant, prosodic contours allow for the mother's intent and affect to be conveyed (approval, disapproval, comfort etc.) which are recognisable even for non-native speakers (Bryant & Barrett, 2016; Fernald, 1989).

IDS is thought to aid infants' lexical development as well as cognitive and emotional development (Snow & Ferguson, 1977), however, it is not what the developing fetus is exposed to most frequently during its development. Thus Experiment 1 aims to assess fetal responsiveness to naturally occurring maternal voice in situ, instead of the previously used story-reading condition.

As previously outlined, research examining fetal responsiveness to maternal voice usually present voice either live or, more commonly, recorded voice and then play it back onto the abdomen. Playing a recording back to the fetus, however, could remove many unique characteristics of the maternal voice, such as bone conductivity, thus altering the voice, which potentially could result in a novel rather than a familiar stimulus. To address this question, Experiment 1 aims to compare spontaneous maternal voice in situ, to the recorded voice of the mother. A further important question to address is whether fetuses' behavioural responsiveness to maternal voice is unique over other commonly occurring sounds. That aim will be addressed comparing fetal behavioural responses to (1) naturally occurring maternal voices, (2) recorded maternal voice, and (3) a recorded everyday auditory stimulus, and comparing all these responses to a (4) control, condition with no-auditory stimulation.

In summary, the main aim of Experiment 1 in Chapter 2 will be to examine whether fetal behavioural responses to social auditory stimuli are different from non-social stimuli, and aims to further examine whether the fetus is able to discriminate between the mothers live and recorded voice.

The aim of Experiment 2: Effects of External Tactile Stimulation on the Fetus

Experiment 2 explores fetal social responsivity in the tactile modality. It aims to provide insight into whether fetuses can discriminate between tactile stimuli of different origin.

Previous recent research has suggested that the fetus displays a behavioural arousal response to maternal tactile stimulation, and this experiment plans to systematically examine different kinds of touch regarding congruency (Marx & Nagy, 2015).

Mother's touch of the fetus is a stimulus when the mother actively touches the fetus via stimulation of her abdomen. Maternal touch is an intentional pressure stimulus, moving the abdominal wall and the internal uterine environment to touch the fetus. Previous research (Marx & Nagy, 2015) found that fetuses displayed increased arm, head, and mouth movements towards maternal touch. However, it remains unknown whether the maternal touch is a unique stimulus to the fetus, and whether the fetus is capable of discriminating between the touch of different origins, such as father's or stranger's touch.

When mothers touch their abdomen frequently it can be argued that the fetus becomes familiar with the touching style (pressure and motion of the mother's hands on the bump), and the internal movements, which go along with it. Father's touch is another potentially familiar stimulus, however, as it is not accompanied by congruent maternal muscle and body movements. A stranger, who may also touch the abdomen, on the other hand, has no practice in the type of touch parents expose their fetuses to, as every mother adjusts the pressure and location slightly differently. Father's and stranger's touch, therefore, represent external touch with different degrees of familiarity and no congruency with relevance to the mother's body.

Based on the above literature review it is expected that fetuses can perceive both auditory and tactile stimulation, and in some extent, are conscious and intentional to be able to respond according to the nature and the origin of the stimulation. Our previous study (Marx & Nagy, 2015) suggests evidence for such differential responsivity, hence the two experiments were designed to separate the two modalities, unlike the previous study where both modalities were put together (Marx & Nagy, 2015). Furthermore, based on the reviewed literature a difference between gestational ages is expected. As it is expected that maturation determines responsivity, fetal age will be taken into account when recruiting mothers for this experiment. Fetuses will span from the 2nd to 3rd trimester and the age of the fetus will be taken into account as a variable when analysing their responses to the stimulation to these two modalities.

Chapter 2 will present Experiment 1 on auditory stimulation and in Chapter 3 will present Experiment 2 on the tactile modality.

Coding and coding system

Based on the above literature reviews it has been highlighted that behavioural responses to stimulation were sparsely measured and if they were, they have usually summarized outcome variables of the different movements (de Vries et al., 1985; Piontelli, 2010; Shahidullah & Hepper, 1993). It is necessary to apply a more fine-grained approach, differentiating among the movement of different body parts of the fetus, including measuring the directionality of the movements using an objective complex coding system developed for the purpose of these studies. Thus both Experiment 1 and Experiment 2 will employ a fine-grained behavioural coding system with frame-by-frame measurements of the movements of the fetus over time.

In order to record fetal movements, a fetal behavioural coding system was developed. The behaviour of the fetuses was coded using frame-by-frame coding with the Noldus Observer System (*The Observer 5.0 Reference Manual*, 2003). After initial explorations of the scans, a coding system was designed that consisted of 20 variables such as arm movements, head movements, mouth movements, hands touching the body/face/uterus, arms crossed, and yawning. The used coding system builds on the previously developed coding system from (Marx & Nagy, 2015) and has been developed further.

An overview of the coded variables and brief descriptions can be found in Table 1c, and Table 1d for the combined variables. Combined variables were created to further investigate fetal responses separated in different categories. Since the literature generally investigates general movements for ease of coding, the coding system has been extended by calculating the appropriate frequencies and durations for the following variables: ‘General movements’ (consisting of ‘Head’ and ‘Arm movements’), ‘Self touch’ (consisting of fetal ‘Body’ and ‘Face touch’), ‘External touch’ (consisting of ‘Uterus touch’ and ‘Face press’), and ‘Inactivity/Resting’ (consisting of ‘Arms-crossed’ and ‘Hands-crossed’).

The accuracy of the coding was in milliseconds (5 milliseconds precisely) that is frame-by-frame. Start and stop times will be measured that allowed to measure frequency (occurrence) as well as duration (how long each movement lasted) of each variable. Both frequencies and the duration of the movements were coded and analysed by the Observer system. The coding system will be further discussed in each experimental chapter.

Table 1c. Coding system developed to analyse fetal movements in utero. All original variables and breakdown of variables for hierarchal variables with descriptions displayed.

Variable Name	Breakdown of Variables	Description
Arm Movements	Starts/Stops	Any visible arm movements
Touch (hierarchal)	Own body	Fetus touches its own body with hand(s), everything apart from the face
	Face	Fetus touches its own face with hand(s)
	Hands-Uterus	Fetus touches the uterine wall with hand(s)
	Stop	Fetus lifts hand off body/face/uterus wall and stops touching
Hands-crossed	Starts/Stops	Fetus makes two fists, which touch each other with the side of the palms
Arms-crossed	Starts/Stops	Arms are crossed over the body, also touching at the interception
Body turning	Starts/Stops	The whole body is turning away/towards the probe
Hiccup	Starts/Stops	quick jerk, starting in the upper torso
Yawning	Starts/Stops	Long opening of the mouth often accompanied by tilting the head backward
Mouth Movements	Starts/Stops	The mouth opens, lips part, and closes, lips back together
Tongue Movements (hierarchal)	Out	Tongue out of the mouth
	Moving in mouth	Only visible in 2D, the tongue is moving in mouth not coming out
	Stops	Tongue stops any movements
Sucking	Starts/Stops	Repetitive mouth, lip and tongue movements resulting in sucking

		movements
Breathing	Starts/Stops	Fetal breathing is described as an inward movement of the chest wall along with an outward movement of the abdominal wall
Stretching	Starts/Stops	Stretching, back bending of the head for more than 2s including straightening of the spinal chord
Hand movements (hierarchal)	Hand movements	General hand movements such as rotations or up and down movements of the wrist
	Fist	Hand and fingers move to form a fist
	Finger Movements	Single/Multiple finger(s) are moving independently
	Stops	All hand/finger movements stop
Face press	Starts/Stops	Face touches uterus wall with forehead or larger facial area
Kicking (Event)		If legs are visible, rapid sudden movements

Table 1d. Combined Variables. Combined variables are computed creating a total number of frequencies and total duration in seconds for each computed variable.

Variable Name	Combination of	Description
General Movements	Arm Movements Head Movements	Both, ‘Arm Movements’ and ‘Head Movements’ are generally referred to as gross body movements.
Self-touch	Body Touch Face Touch	Both, ‘Body’ and ‘Face touch’, are forms of tactile self-stimulation.
External touch	Uterus touch Face press	Both, ‘Uterus touch’ and ‘Face press’ involve the fetus touching the uterine wall.
Inactivity/Resting	Arms-crossed Hands-crossed	Both, ‘Arms-crossed’ and ‘Hands-crossed’, are positions where the fetus is not moving, but inactive/ in a “resting” position instead.

Chapter 2: Voice Experiment

Experiment 1: Frame-by-frame analysis of fetal behavioural responses to the differential auditory stimulation

Introduction

The mother's voice is a familiar and special stimulus to the newborn (DeCasper & Fifer, 1980). When newborns are given the choice between a story read out by a female stranger or the mother, newborns actively regulate their sucking behaviour on a non-nutritive dummy in order to hear the mother's recording over a stranger's. The hearing should be possible from 16wGA when auditory structures are formed (López-Teijón, García-Faura, & Prats-Galino, 2015; Sohmer, Perez, Sichel, Priner, & Freeman, 2001). And the fetus should be capable of experiencing and responding to all sounds from 28 wGA (Brezinka, Lechner, & Stephan, 1997). Over the course of the fetal development and its auditory maturation, the fetus is capable of hearing the mother's voice that most likely is one of the most prominent auditory stimuli. The fetus is exposed to the mother's voice on a daily basis, it can hear her whenever she speaks. Moreover, her voice is not purely an external auditory stimulus but also mediated through bone and fluid conductivity and internal vibrations as the body resonate when the mother speaks (Gerhardt & Abrams, 1996; Querleu et al., 1989). Hearing the mother's voice is hypothesized to promote early mother-infant bonding (and infant-mother bonding respectively), and language acquisition (Klaus & Kennell, 1976). Early exposure to the maternal voice has beneficial effects on the developing brain and auditory system of the fetus and newborn and are related to later emotional and social development (Fifer & Moon, 1994).

In preterm infants singing and speaking to the infant resulted in significantly fewer critical medical events, in an improved physical state and better developmental outcomes (Filippa, Devouche, Arioni, Imberty, & Gratier, 2013; Krueger, 2010; Picciolini et al., 2014). In newborns, exposure to the voice of the mother facilitates intermodal perception necessary for facial recognition of the mother. Presentation of the mothers' face accompanied by the mothers' voice allows the neonate to recognise its mother, which would not easily be possible so soon after birth if the newborn was not familiar with the mothers' voice (Sai, 2005).

Results from DeCasper and Fifer (1980) study shows that the newborns respond to maternal voice even with minimal post-birth auditory exposure. However, even though the postnatal exposure might be minimal, the fetus is exposed to the maternal voice for much longer as it is capable of hearing the mother while it is still developing in utero (Querleu et al., 1989). The results to support this view comes from research investigating the fetal responsiveness to external auditory stimulation in utero (Hepper & Shahidullah, 1994; Shahidullah & Hepper, 1994). Such explorations were possible only since the development of 2D ultrasound (Moon & Fifer, 2000; Pino, 2016; Shahidullah et al., 1994; 1996; Sirak, 2012).

In the early stages of examining the fetus researchers examined the natural development and first occurrences of fetal movements (de Vries et al., 1982; 1985; 1988). These studies were soon followed by further studies examining fetal responses to pure tone stimulation (Hepper & Shahidullah, 1994; Shahidullah & Hepper, 1994) discovering earliest responses to a 500 Hz tone at 19wGA. In this study, a loudspeaker was placed on the maternal abdomen examining fetuses (19-35 wGA) movement responses to 100 Hz, 250 Hz, 500 Hz, 1000 Hz, and 3000Hz (Shahidullah et al., 1994). Fetuses first responded to lower frequencies (100 Hz and 250 Hz) and over the course of maturation increased their responsiveness to higher frequencies. Responsiveness to 250 Hz and 500 Hz was observed for all fetuses at 27wGA, and responses to higher frequencies such as 1000 Hz and 3000 Hz were observable in all fetuses from 33 wGA (Shahidullah et al., 1994). It is proposed that changes in frequency responsiveness reflect the neurological maturation of the auditory system and sensitivity to lower frequencies promotes language acquisition (Shahidullah et al., 1994). The changes in frequency responsivity reflect the underlying maturation of the cochlea, which begins at 10-12 wGA and has been proposed to have matured by 30-35 wGA (Birnholz & Benacerraf, 1983; Pujol et al., 1992; Shahidullah et al., 1994). The neural development of the auditory system such as the ventral cochlear nucleus accelerates development between 18-33 wGA and is most likely closely linked to the fetal responsiveness to auditory stimulation (Nara, Goto, Nakae, & Okada, 1993). Thus the fetus is capable of perceiving its external auditory environment, being able to respond to low frequencies from 19 wGA, and by 27wGA a wider auditory perceptive repertoire has developed and continues developing until the auditory system has fully matured (Birnholz & Benacerraf, 1983; Nara et al., 1993; Pujol et al., 1992; Shahidullah et al., 1994).

On the basis of the findings on fetal hearing, research has continued to examine fetal responsiveness to maternal voice and compare responses to that of a female stranger. The general research paradigm used to examine fetal responsiveness to sounds comprises two minutes of no stimulation, which allows to set the baseline response and make sure the fetus is exposed to no stimulation prior the experimental manipulation to ensure that the fetal response is elicited by the stimulation rather than due to chance, followed by two minutes of the experimental stimulation to ensure a long enough exposure of the stimulus to the fetus, which is then followed by another two minutes of no stimulation, another baseline condition (Kisilevsky et al., 1992; 2003; Lee & Kisilevsky, 2013). As part of the methodologies, studies commonly use loudspeakers positioned on the maternal abdomen for playing the pre-recorded voice of the mother and a stranger to the fetus, under controlled conditions. As an outcome measure, studies have predominantly used fetal heart rate (FHR) changes (Kisilevsky et al., 1992; 2003; Lee & Kisilevsky, 2013).

Kisilevsky et al. (2003) exposed the fetus to a recording of a stranger versus the mother during the experimental condition and examined changes in FHR. An increased FHR response was found in near-term fetuses in response to maternal voice, whereas a decrease in FHR was found in response to the strangers' voice. Thus it was claimed that the FHR increase demonstrates a familiarity effect whereas the FHR deceleration was due to a novelty response (Kisilevsky et al., 2003). In another study, Kisilevsky et al (2009) examined the differential FHR changes to maternal voice versus fathers and a strangers' voice speaking in a native or a foreign language, played back via loudspeakers that were placed on the maternal abdomen (Jacquet et al., 2009). Findings from this study, however, are contradictory to their previous findings (Kisilevsky et al., 2003). When the fetus is familiarised with the voice recordings of their mother and a stranger, no differences were found in FHR response (Jacquet et al., 2009). Although the authors expected a difference between the effects of mother's and stranger's voice, there was no difference in how the fetuses responded to the voices. The explanation for this result, according to Kisilevsky et al. (2009) is that the stimulation time of 2 minutes was too brief to elicit a response. This however it might not be the case, as fetal responses to maternal auditory stimulation could potentially be found almost instantaneously (see Chapter 3) (Marx & Nagy, 2015).

This undifferentiated response can, however, be due to the presentation method. Presenting the mother's voice externally via loudspeakers results in the loss of many special characteristics the mothers` voice possesses. The mothers` voice travels throughout the body and is conducted via bone and fluid conductivity thus reaches the fetus not just externally but also internally, attaching unique properties to the maternal voice which cannot be replicated by a loudspeaker which is 10cm away from the abdomen (Gerhardt et al., 1996; Richards, Frentzen, Gerhardt, McCann, & Abrams, 1992). Thus the indifference in FHR response to the familiarised recordings of the voices of the mother and the stranger while retelling the same story might actually reflect that the fetus is capable of remembering the story of both mother and stranger, with the mother being seen as a similarly "novel" voice as the stranger was. When they respond the same way to both voices, it is possible that they remember the story, but not the voices. Studies have previously found that fetuses are capable of remembering and responding to a familiarised TV theme tune whilst in utero and they are also capable of remembering said tune following birth (Hepper, 1991). This response was characterised by an increase in fetal movements whilst the newborns decreased their movements when the tune was presented to them (Hepper, 1991).

DeCasper, Lecanuet, & Bussner (1994) also used loudspeakers to present the auditory stimuli to the fetus. Over the course of 4 weeks' prior the experiment participating mothers were split into two groups and asked to recite one of two target rhymes, 3 times a day, every day. By the time of testing all fetuses were 35wGA. Tape recordings of the two rhymes were created with a female stranger reading out the rhymes. These were then played back to the abdomen using loudspeakers and FHR was recorded. A FHR decrease to the novel rhyme was suggested to show that the fetus became familiar with recurrent maternal speech sounds (DeCasper et al., 1994). However, when taking previous research into account, the outcome measurement was not necessarily the fetus beginning to differentiate between maternal speech sounds and control, but the fetus displaying memory functioning of the cited rhyme, the same way they can remember music (Qahtani, 2005) and TV theme tunes (Hepper, 1991). By the third-trimester, the fetus is already familiar with and capable of recognising the mothers' voice (Marx & Nagy, 2015; Shahidullah et al., 2007).

Studies from other laboratories investigating the effects of mothers' voice, and using loudspeakers, similarly to Kisilevsky et al.'s studies (2003, 2009), found the opposite effect, a decrease in FHR to maternal voice (Lecanuet et al., 2002), compared to Kisilevsky et al. (2003, 2009) work, suggesting that there are possible methodological issues regarding stimulus presentation underlying these differential results (Gregg, Clifton, & Haith, 1976). However, when Hepper (1993) compared the two presentation methods, live voice versus recorded voice of the mother, a differential response to the two methods was found. In Hepper et al.'s study (1993) the outcome measurement was fetal movements. The use of fetal movements instead of FHR measurements allows for the same measure to be used postnatally, as the fetal movement repertoire is completed by 36wGA equalling that of a newborn (Hepper et al., 1993). Of course, heart rate measurements are also available prenatally and postnatally, however exploring responses by examining the fetal movements allows us to see more than just an increase or a decrease of response. It allows us to see where and what the fetus is touching when. This kind of data allows researchers to gain further insight into fetal responses to external stimulation and has the potential to provide a wealth of additional information about the type of response, as opposed to the FHR which does not allow for fine-grained discrimination as such. It has been proposed that fetal movements are the most important measurement of fetal health, as movements are sensitive to oxygenation, during development in comparison to other measurements FHR and breathing (Natale et al., 1985; Natale, Clewlow, & Dawes, 1981).

Fetuses displayed significantly fewer movements when the mother was speaking live compared to the mother's recording played back to the abdomen (Hepper et al., 1993). The mother speaking live is obviously a more familiar stimulus to the fetus rather than presenting her voice via recordings using loudspeakers near the mother's abdomen. In the case of the recorded playback, the voice is stripped from its unique characteristics and presumably results in the same response (increased movements) to what the strangers' voice elicited via loudspeakers (Hepper et al., 1993).

In summary, based on the inconclusive results from the above studies, in order to examine fetal responsiveness and discrimination between mothers and strangers' voices, both voices would need to be presented live, instead of using loudspeakers. Hepper, Scott, and Shahidullah (1993) examined the difference in fetal movements to recorded voices of their mothers and strangers at 36wGA. Fetuses did not discriminate between the recording of the mother and the stranger. However, fetuses did discriminate between a recording and the mother's live spoken voice. These findings emphasise the importance of presentation methodology of the mothers' voice. Although Hepper et al. (1993) examined differences between the two presentation methodologies, another methodological issue remains. The fetus has a preference for mothers live speaking as compared to the sound of her voice presented using a loudspeaker close to the abdomen (Shahidullah & Hepper, 1993). However, studies investigating fetal and newborn responses often have the mother reading a story, nursery rhyme, or ask the mother to speak motherese although research has shown that even newborns prefer the mothers spoken voice compared to motherese (Shahidullah & Hepper, 1993), highlighting the importance of not just the source location of the stimulus but also how the mother speaks to the fetus or newborn. Although it is possible to have the mother read out a nursery rhyme or story in her normal voice, the most natural would be using maternal live, spontaneous spoken voice.

A recent study which has examined differences between a mother reciting a familiar nursery rhyme live or recorded, found no differences in fetal movements but found differences in FHR responses with a slight deceleration to live voice compared to recorded voice (Krueger & Garvan, 2014). The FHR results from Krueger et al (2014) therefore add to the pool of mixed results from previous research investigating FHR responses to maternal voice. The increase of fetal movement responses, however, are not in line with previous research where a decrease of fetal movements was observed to live voice compared to a recording (Shahidullah et al., 2007).

Voegtline et al. (2013) further examined fetal motor responses to mothers reading in situ of a neutral passage and found evidence for a decrease in motor movements. This response was apparent for the first 10 sec and was accompanied by a FHR deceleration indicating an orientating response (Voegtline et al., 2013). Unlike other studies, Voegtline et al. (2013) manipulated the baseline condition. The total baseline recording lasted 50 minutes and was split into two variations. For the first 25 minutes of the scan, all mothers were responding to questions of a questionnaire and were then offered to either rest the remaining 25 minutes of the ultrasound scan with dimmed lights and eyes closed (resting baseline) or continue conversing informally (speaking baseline) with the experimenter until the experimental condition began. Following the baselines, lights of the ‘resting baseline’ were turned back to normal and all mothers were asked to read aloud from a neutral passage for 2 minutes. Findings from using the ‘speaking baseline’ condition resulted in fetuses decreasing movements and FHR to mothers’ onset of reading whereas an increase in movement and FHR was found for the ‘resting baseline’. These findings take into account the mothers’ previous state on the fetal movements and FHR. Voegtline et al. (2013) showed that there were no differences in fetal movements during the baseline conditions regardless of mothers’ state, but at the onset of the mother reading aloud fetuses in the resting baseline increased their movements whereas fetuses whose mothers were already talking (speaking baseline) did not show an additional increase in movements. However, fetuses in the speaking baseline reduced their movements in the subsequent seconds after the mother started to read aloud when compared to the baseline. This decrease in movements when mothers were reading aloud was not observed in fetuses from the resting baseline. This research showed that fetuses display an orientating response to the onset of mother’s reading which peaks at 5 seconds after the onset of the stimulation and returns to baseline 7-8 seconds post-stimulus onset. Results from this study stress the importance of the maternal states in the baseline, as they have been shown to influence fetal responses to the experimental stimulation (Voegtline et al., 2013). Another important insight can be gained from Voegtline et al.’s (2013) study. The fetal response was immediate and returned back to baseline levels after 7-8 seconds, implying that studies who only focus on the whole 1-3-minute segment of stimulation are likely to miss responses by averaging their results over such a large time interval.

The observed orientating response supports the results of previous research (Hepper et al., 1993) investigating live voice compared to recorded voice, however, the results from Voegtline et al. (2013) show that fetal responses are also influenced by the baseline. As fetuses responded differentially between the two baseline conditions (Voegtline et al., 2013). The changes in fetal behaviour from the resting baseline to when the mother is reading were expected since a stimulus was introduced. However, the interesting finding is that fetal response changed from the speaking baseline condition at stimulus onset, reading of a neutral passage (Voegtline et al., 2013). If neutral reading was a true stimulus, meaning that it is a valid representation of the mothers' normal voice, there should hardly be any change between the fetal responses between the speaking baseline and stimulus onset. Although it could be argued that the experimenter's voice was also present in the speaking baseline condition, Voegtline et al. (2013) found that the fetal response was only a brief response during the first seconds of reading, and movements returned back to those of the baseline level, afterward.

Thus this brief significant deceleration might suggest that the observed results are due to the changed maternal prosody which fetuses perceived as a novel stimulus and responded differentially. These results may be in parallel to studies which found that listeners are aware whether someone is reading a passage out aloud or is producing spontaneous speech (Blaauw, 1994). It is suggested that changes in prosody are the most important factor in this discrimination (Blaauw, 1994), and the fetus also appears to be capable of differentiating between the two types of prosodies. Thus in order to measure a 'true' fetal response to the mothers' voice the reading out a passage is not the most favourable presentation method and in order to examine the "natural response" of the fetus to maternal voice, researchers should try to present the mother's voice as spontaneous speech.

Prenatal exposure to the primary caregiver is speculated to aid the development of attachment and recognition of and to the caregiver and may prepare the newborn to respond preferentially to its mother providing important feedback and recognition which in turn aids the mother-infant bond and communication (Hepper et al., 1993). Animal studies investigating the importance of mothers' call showed that alteration and deprivation of the mothers' call result in an atypical response or to identify their mothers call in ducklings (Gottlieb, 1985) and quails (Lickliter & Virkar, 1989). Thus both, human and animal studies, suggest that the exposure to mothers voice plays an important role in prenatal development (DeCasper et al., 1994; DeCasper & Fifer, 1980; Gottlieb, 1985; Lecanuet & Schaal, 1996; Lickliter & Virkar, 1989; Spence & DeCasper, 1987).

Studies on the human premature have investigated whether the exposure to maternal voice via bone conduction in the Neonatal Intensive Care Unit has beneficial effects (Picciolini et al., 2014). It was hypothesised that the mothers' voice is a unique source of sensory stimulation for the developing child, exerting a positive acoustic source necessary for adequate development (Aguado et al., 2003). In Picciolini et al's study (2014) newborns were connected to a transducer bone conductor through which the mother's voice was transmitted. Mothers read passages from the "Little Prince" to newborn infants who were born prematurely at 29 wGA with three sessions a day, for 21 days. Infants were tested at 40wGA, 3 and 6 months following treatment. Findings from this study suggest that exposure to the mothers' voice was beneficial to the preterm babies' neuro-behavioral and autonomic development at 40wGA and 3 months (Picciolini et al., 2014). Infants receiving stimulation showed more stable skin colouration, lower heart rate, increased visual attention, and improved quality of movements compared to control infants who did not receive the additional stimulation of the maternal voice (Picciolini et al., 2014). At 6 months, however, no differences were found between control and treatment groups (Picciolini et al., 2014). Presenting the voice through bone conduction mimics the characteristics, as much as possible, of the maternal voice in the womb. These findings suggest that auditory stimulation through bone conductivity could promote the normal physiological development of the sensory systems and possibly aid the organisation of a functional cortex and thus facilitate neurodevelopment (Sohmer, Perez, Sichel, Priner, & Freeman, 2001). Krueger et al. (2010) and Cevasco et al. (2008) reported similar results where the maternal voice appeared to be beneficial to premature infants neurodevelopmental and sensory outcomes (Cevasco, 2008; Krueger, 2010).

Thus previous research points towards the importance of the mothers' voice for infant development, implying that the mother's voice is of great importance throughout the pregnancy possibly aiding the promotion of normal development. The maternal voice is special because it travels internally through the body, is transmitted through bone conduction, and is the most familiar animate auditory stimulus which the fetus hears for the entire pregnancy. Once fetal auditory channels have developed and the brain is capable of processing auditory stimulation, the mother's voice is a constantly present stimulus for the fetus.

Based on previous research it is even more important for the ecological validity of fetal auditory studies, that the effects of the spontaneous live spoken voice of the mother are used as a stimulus when measuring fetal behavioural and physiological responses. Taking away the naturally occurring properties of the mothers' voice is likely to alter key features of the stimulus and possibly alters the fetal responses thus leading to inconclusive results across studies.

Aims of Experiment 1

Following the above conclusion, the first aim of this experiment is to examine whether the mothers' voice is a special auditory stimulus to the fetus. This aim will be explored by comparing maternal voice to common, inanimate stimulation as well as to a silent, control condition in order to eliminate that the observed responses are purely based on an auditory response rather than to the properties of the maternal voice.

Aim 1: Differentiation between Live and Recorded Maternal Voice

As all previous studies, but one study (Hepper et al., 1993), primarily present the mothers voice over loudspeakers, this study aims to investigate the methodological differences in the auditory presentation of the mother's voice (live versus recorded), in order to examine whether fetuses indeed differentiate behaviourally between the mothers live and recorded voice. This aim will be tested by comparing the two presentation methods and examine fetal behavioural responses as outcome measures. Every day the fetus is exposed to the spontaneous voice of the mother, thus for the purpose of this experiment, the mother's voice will be spontaneous in all conditions. Reading a nursery rhyme or story is likely to alter the prosody of the voice (Blaauw, 1994), thus the most natural fetal response can be expected from spontaneous natural speech, which will be featured in both live and recorded conditions.

Hypothesis 1 predicts that fetuses react differently to mother’s live voice compared to mother’s recorded voice, with a preferential response to the live voice over the recorded stimuli. Additionally, it is expected that fetuses will show a stronger response to the mother’s live voice than to recorded voice, compared to the control condition.

Aim 2: Differentiation between social and non-social stimuli

In order to ensure that the fetal reaction is not resulting from a simple auditory stimulation, an inanimate everyday sound will be included to which behavioural responses of the voice conditions can be compared to. Thus an auditory non-voice (sound) condition was included in this experiment as an additional control condition, unlike previous research (Kisilevsky & Hains, 2011) which generally disregards appropriate control conditions (DeCasper, Granier-Deferre, Fifer, & Moon, 2011). The inclusion of a sound condition also allows examining differences between responses to social stimuli versus commonly exposed environmental non-social stimuli. The everyday sound will also be compared to the control condition. This allows examining whether the responses are indifferent to that of the control (Marx & Nagy, 2015) or whether responses are similar to any of the other voice conditions. It is, of course, possible that there is a response to the auditory stimulation. If that is the case we expect the response to be weaker than the response to the mother’s voice conditions, meaning that the mother is a unique stimulus for the fetus.

Hence this experiment aims to examine and compare fetal movement responses to the most naturally occurring maternal stimuli, spontaneous live speech, with recorded spontaneous speech, a familiar everyday sound, and a silent control condition.

Hypothesis 2a predicts that all three auditory conditions (live, recorded voice, everyday noise) would elicit a behavioural response from the fetus when compared to the silent control condition.

Hypothesis 2b predicts that the everyday noise condition elicits a different response to the control condition.

Hypothesis 3 predicts that fetuses react differentially to maternal live voice compared to an inanimate control auditory stimulus.

Aim 3: Maturational differences

A further aim of this experiment is to further examine the maturational differences in responses between second- and third-trimester fetuses to the different conditions. Although studies have shown that the auditory structures are formed and the earliest responses appear by 16 wGA, the fetus continues developing throughout gestation and the responses change over time (López-Teijón et al., 2015; Shahidullah et al., 2007; Sohmer, Perez, Sichel, Priner, & Freeman, 2001). The fetus is capable of experiencing and reacting to all sounds from 28 wGA (Brezinka et al., 1997), thus changes in responses over the course of gestation, and differences between younger and older fetuses are to be expected (Marx & Nagy, 2015).

Hypothesis 4 thus predicts that the behavioural responses will be more pronounced and differentiated across the conditions in the more mature, third-trimester fetuses compared to second-trimester fetuses.

Aim 4: Time-interval analysis

The fourth aim is to measure the behavioural responses with a detailed coding system that is specifically designed to monitor the available movement repertoire of the fetus, with frame-by-frame analysis to explore the fetal behavioural responses further. Previous studies described general movements of the fetus instead of individual movements, which might result in the loss of reactions depending on the analytical approach used (Shahidullah et al., 2007). Thus this coding system focuses on individual movements which have been developed further since the pilot study for this experiment (Marx & Nagy, 2015). Additionally, for the purpose of further analyses, the detailed coded variables have been reduced into four groups, general movements, self-touch, external touch, and inactivity/resting.

Moreover, the temporal resolution of the analyses will be examined in more detail, by using different temporal windows to investigate how the responses appear and evolve over time.

Hypothesis 5a examines fetal responses throughout different time-frames of the 2-minute stimulation period in order to examine how fetal responses change and evolve over time and to examine how early the responses to the stimulation appear. It is also expected to find differences in the strength of responses over time.

Hypothesis 5b proposes that fetuses will show responses as early as the first 10-15s of stimulation.

Methods

Design

In this 4x2x2 mixed experimental design the independent variable had four within-subject levels: live maternal voice, recorded maternal voice, road noise, and no auditory stimulation. The two levels of between-subject factors were gestational ages of the fetuses (second- or third-trimester, 21-26, and 27-35 wGA, respectively) (see Figure 2a).

The dependent variables consisted of the frequencies and durations of fetus' behavioural responses (in total there were 20 coded variables such as arm movements, head movements, mouth movements, hands touching the body, arms crossed, and yawning; plus, the 4 above mentioned additional computed variables) (See 'Coding System' section and Table 2a for the full coding system and for computed variables see Table 2b).

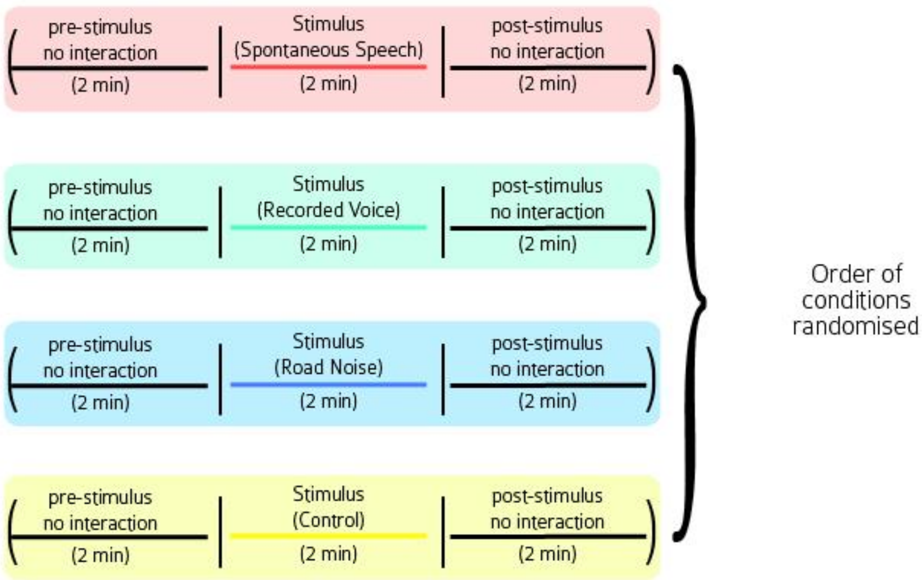

Figure 2a. Overview of the experimental procedure. All conditions were randomised both within and between participants. Each condition lasted 6 minutes in total, with 2 minutes per subsection (pre-stimulus, stimulus, post-stimulus). During pre- and post-stimulus sections of the experimental conditions, no stimulation occurred.

Participants

30 Mothers with low-risk singleton pregnancies (21-35 wGA, Mean = 27.21 weeks, SD = 4.41) were recruited via Hermes, Facebook and word of mouth in order to ask them to participate in this experiment. Participants were divided into two groups depending on fetal gestational age; second trimester ('younger' fetuses ≤ 27 gestational weeks, N = 13), and third trimester ('older' fetuses >27 gestational weeks, N = 17). Participating mothers' age ranged from 24-36 years (Mean = 27.96 years, SD = 3.06 years).

In order to participate, mothers were required to fulfil a number of inclusion criteria: 1) being between the ages of 18 and 36, 2) have had a normal of 18.3-30 BMI (World Health Organization, 2000) before pregnancy, 3) non-drinking/smoking/drug taking during the time of pregnancy, 4) the pregnancy was medically complication free, and 5) they must have had their 20-week check-up scan with the National Health Service (NHS) in order to ensure the health of the fetus prior to participation.

Time of gestation was chosen primarily to ensure the health of the fetus after the 20-week check-up but also, it coincided with the developmental stage when the fetus has already developed its major organs and sensory abilities by then (see Chapter 2 for more details). From that age, fetuses will mainly continue to grow in size and develop further. This also means that assuming the fetus is healthy, there is no risk of possible harm to the fetus during the study. Finally, between the gestational ages of 21-35, the fetus is an ideal size to perform the 3D/4D ultrasound scan, as the intrauterine environment regarding amniotic fluid levels and fetal positions are ideal in order to achieve a high-quality picture.

Materials

Participant information sheet and consent form (Appendices 1 and 2) were used in order to obtain signed informed consent to participate in the study and to being the voice and video-recorded during participation. Mothers were also asked for written permission for the use of imagery for publication and illustration purposes.

Demographic questions

A demographic questionnaire (see Appendix 3) was administered consisting of questions regarding the age of the mother, gestational week of the fetus, marital status, number of dependents, education, health status of mother and the fetus, smoking during and prior pregnancy, attendance at antenatal classes, as well as time spent engaging talking to the baby/touching the bump by oneself/family member/strangers in hours per day.

The Beck Depression Inventory (BDI)

As a background measure of maternal mental health, that is known to affect fetal development (Dieter, Field, Hernandez-Reif, Emory, & Redzepi, 2003; Emory & Dieter, 2006) the Beck Depression Inventory (BDI) (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) was administered to assess expecting mothers' current level of depressive symptoms. This self-reported questionnaire consists of 21 items. Items consist of a possible choice of four answers of which the participant has to select the most suitable characteristic at the time of the measurement. For example 1) I do not feel sad, 2) I feel sad, 3) I am sad all the time and can't snap out of it, 4) I am so sad or unhappy that I can't stand it. Items are scored on a point scale from 0-3.

Scoring of the BDI (Beck et al., 1961) involves adding up scores of the 21 items. Items begin at 0 – with no depressive symptoms such as I do not feel sad, I do not feel like a failure, or I do not cry more than usual. The next level is 1 which represents answers such as the following: I feel sad, I feel I have failed more than the average person, and I cry more now than I used to. Statements scored with 2 points include the following: I am sad all the time and can't snap out of it, as I look back on my life, all I can see is a lot of failures, and I cry all the time now. 3 points represent the most severe depressive symptoms such as 'I am so sad or unhappy that I can't stand it', 'I feel I am a complete failure as a person', and 'I used to be able to cry, but now I can't even cry even though I want to'. The minimum score is 0 and the maximum score is 63. The total score of the 21 items relates to the levels of depressive symptoms. These levels range from 1-10 ups and downs considered normal, 11-16 mild mood disturbance, 17-20 indicates possible borderline clinical depression, 21-30 moderate depression, 31-40 severe depression, and over 40 suggests extreme depression. According to the BDI, a persistent, - meaning if the test is repeated - score of 17 or above indicates the need for professional diagnosis and possible treatment.

Antenatal Maternal Attachment Scale (AMAS)

As a second maternal measure, Condon's (1993) 21 item self-reported paper and pencil questionnaire 'Antenatal Maternal Attachment Scale' (AMAS) on maternal thoughts and feelings about the developing baby was included to assess maternal-fetal attachment (Condon, 1993). The AMAS measures the following three factors: quality of attachment, time spent in attachment mode (or intensity of preoccupation) and a global attachment score.

Items investigating the time spent in attachment mode are statements such as "Over the past two weeks I have found myself talking to my baby when I am alone". Possible answers to this item are "not at all", "occasionally", "frequently", "very frequently", and "almost all the time I am alone". An example for an item exploring the quality of attachment is "when my baby is born I would like to hold the baby" with answers being "immediately", "after it has been wrapped in a blanket", "after it has been washed", "after a few hours for things to settle down", and "the next day".

Scoring of the AMAS (Condon, 1993) involves scoring individual items using the scoring key provided. The questions are separated into two groups: Quality of attachment and time spent in attachment mode. Overall items are scored from 1-5, with 1 being a low attachment and 5 being a high attachment. Items in brackets are reversed scored. Items (3), (6), (9), (10), 11, (12), 13, (15), (16), and 19 are added up and load onto the quality of attachment, with a maximum score of 50. Items (1), 2, 4, (5), 8, 14, 17, and (18) are summed up in order to receive the score for time spent in attachment mode/intensity of preoccupation, with a maximum score of 40. Item 7 ("Over the past two weeks I have felt that the baby inside me is dependent on me for its well-being") does not load on either of the two factors, however, is included in the global attachment score, where its value is reversed. The global attachment score is calculated by summing the quality of attachment and time spent in attachment mode factors together with item 7 and the highest achievable score is 95.

Equipment

Recording the mother's voice

Voice recording topics

A sheet containing 23 sample questions was created to initiate communication during maternal recordings and maternal live voice conditions, to help prevent as many speech pauses as possible. Sample questions included questions such as "how are the preparations for the baby?", "What is keeping you busy these days?" and "What are your plans for the weekend?" (see Appendix 4).

Recording equipment and playback

An iPhone 5S using the 'Voice memo' app was used to record mother's voice. The voice recording was outputted using a "Microlab MD312" wireless loudspeaker, which was placed 10 cm besides the mothers' abdomen. Stimulus intensity was set to 95dBA (Jacquet et al., 2009) to achieve the approximate level of a normal conversation at the maternal abdomen, as measured by

‘Precision Gold’ sound-level meter (model N05CC) (Cave, Garvan, & Krueger, 2015; Gray, 2000).

Ultrasound recording

The 'GE Voluson i' Ultrasound System, 'RAB4-8-RS4D' probe and ultrasound gel was used to perform the 4D ultrasound scan. The scan was recorded on a 'MacBook Pro’ using 'Game Capture HD' software for 'MAC OS X' from Elgato. The 'MacBook Pro’ was connected to a high definition game recorder, 'Elgato Game Capture HD', which in turn was connected to the ultrasound system via VGA to HDMI converter. In order for the mother to being able to follow the scan, the signal was outputted via the 'Elgato Game Capture HD' to a 17inch television positioned at the end of the scanning bed.

Advantages and Limitations of 4D Ultrasound

4D Ultrasound offers many advantages over traditional 2D ultrasound, particularly by adding 3-dimensionality as well as a time-based resolution to visualize the movements of the fetus in great detail, such as the changing facial expressions, eye movements, finger and other fine motor movements. 4D also allows us to visualise all limbs across all plains, thus resulting in seeing the positioning of arms and hands clearly.

Although 4D ultrasound has many advantages compared to traditional 2D ultrasound, it also has disadvantages. The disadvantage of 4D ultrasound is that the acquisition speed is not as fast as traditional 2D ultrasound, as the image needs to be computerized and reconstructed therefore some components of motion cannot be visualized, i.e. breathing movements. 4D ultrasound is not capable of capturing quick components of motion such as tempo or speed. Due to the fetal position in utero the placenta or umbilical cord can cover the fetal face, however, a skilled sonographer is able to change the angle of the visualization in most cases to scan past these and achieve a high-quality image. Furthermore, as the fetus grows and the uterine space becomes more limited the acquisition window becomes smaller, and it is not possible to capture the fetus in full. However, during these experiments sonographers focused on the face and upper abdomen, which was possible regardless of the gestational age of the fetus.

During the experiment, 4D was the preferred scanning method, however, if the fetus moved into a position where the use of 4D was not suitable the scan was continued in 2D as it is a common practice. This results in a consecutive scan despite scanning method. 2D was preferred when, for example, the fetus had its legs above the head and the arms, hands, and head of the fetus could not be visualised properly.

Video recording

A 'Sony HDR CX220E’ camera mounted on a tripod was used to record both video and audio of the mothers’ interactions focusing on the participants’ face and stomach including the ultrasound system to allow for later synchronisation during analysis.

Pilot Study: Everyday sound condition development

A pilot experiment was conducted in order to select and validate an ecologically valid common everyday sound to be presented in this experiment.

Criteria for the everyday stimulus included the following: the stimulus should contain no human voice, as this needs to be a naturally occurring non-social stimulus. The selected stimulus must not be music either, as previous studies have examined the effects of music on the fetus and found an independent FHR response to music compared to mothers’ voice (Sontag, Steele, & Lewis, 1969), a response to as well as retention of music (Granier-Deferre et al., 2011; Partanen, Kujala, Tervaniemi, & Huotilainen, 2013), as well as a musical preference (Hepper, 1991). The selected stimulus had to be a frequently occurring continuous stimulus everyone is naturally exposed to by living in an urban environment. It must not be frightening, like alarms, to avoid a startle reaction.

Stage 1: Stimulus collection

After considering these criteria, the experimenter collected the 4 most common stimuli that met these criteria. These included sounds of the ocean, bird and insect noises, the sound of the rain, and road noises.

Stage 1.1: Ranking of the pilot stimuli and results

Pilot participants (N = 10, 5 males and 5 females, aged 18-32) were asked to rank the 4 stimuli (ocean, bird and insect noises, rain, and roads). Participants were invited to list any additional stimuli which they considered matching the criteria.

Road sounds were ranked first by 90% of the participants. None of the suggested stimuli by the participants matched the experimenters' criteria, i.e. phone ringing, the sound of machines, clock ticking and were therefore excluded in the analysis. Thus the most commonly occurring non-verbal everyday sound in the area of Dundee (Scotland) was found to be road sounds. In the next stage, exemplars of road sounds were collected and tested.

Stage 2: Road sound selection

In the second stage, 10 audio stimuli for the road noise were collected by the experimenter and her supervisor. Out of those, the four most suitable road sounds which closely resemble sounds in the area in/around Dundee city were selected.

Stage 2.1.: Ranking and results of road sound selection

The same participants as in Pilot Study Stage 1 (see Stage 1.1, N = 10, 5 males and 5 females, aged 18-32) were asked to rank the previously selected four road sounds. Participants were asked to rate the four audio presentations of light to medium traffic road stimuli from the most often perceived to least common. The audio file presentation was counterbalanced within and between participants. Most participants (80%) chose stimulus No. 4 as the most common, which was then adopted in the study to represent the everyday auditory non-human stimulus.

Ethical Considerations

This research was approved by University of Dundee Ethics Committee (UREC 14132). The Participant Information Sheet and Consent Form can be found in Appendices 1 and 2.

Coding System

The video data were analysed using the Noldus Observer System and coded frame-by-frame. The videos were reviewed exploring the nature of movements the fetus made and the visibility of the movements. A coding system used in a previous study by the experimenter (Marx & Nagy, 2015) was utilized. The codes were reviewed and further developed while previewing the recorded fetal movements. The main movements that were observed and coded were the following: arm movements, arm positions, hand movements, fetal touching, mouth openings, sucking, tongue protrusion, body rotations, stretches, fetal breathing, and kicking (see Table 2a). Combined variables can be examined in Table 2b.

Touch

Fetal touch was divided into sub-categories namely, self-touch of the own body, self-touch of the face and touching of the uterine environment. Self-touch of the body included the fetus touching its body with its hands. This code did not contain touching the face. Facial touch describes the fetus touching its head including a face with one or both hands. Touching of the uterine environment describes the fetus touching the uterine wall or placenta with its hands. These codes are in a hieratical order (uterus, face, body), this is due to the nature of the coding software and means that if the fetus is touching his face and body simultaneously face will be coded and body will be disregarded.

Likewise, if the fetus is engaging with the uterine environment facial touch or bodily touch will not be coded.

Hand and Arm Movements

General gross motor arm movements were coded. Furthermore, two common positions of the arms and hands were coded: one being arms crossed, while the other being hands cross. Arms crossed describe a crossing of arms across the body or in front of the face. Hands cross describes the fetus having hands up in front of the face parallel to one another, both hands touching one another at the side of the hand.

Hand movements

Hand movements were coded ranging from rotational hand movements of the wrists, overproducing a fist, and isolated finger movements. Due to the nature of Noldus Observer System hand movements are coded hierarchal, with isolated finger movements being at the top followed by the formation of a fist and wrist rotations.

Body Movements

Fetal gross body rotations were coded when the fetus was turning towards or away from the probe.

Mouth movements, hiccup, yawning, breathing

Mouth movements are coded when the fetus is opening and closing its mouth. Mouth movements are discriminated from yawns. Mouth movements are much shorter in duration in comparison to yawns. Yawning is described as a prolonged and wide opening of the mouth followed by a quick closure often accompanied by a retroflexion the head which can be accompanied by the lifting of the arms simultaneously and is usually non-repetitive (de Vries et al., 1982). Hiccups are characterised by a powerful contraction of the intercostal muscles and diaphragm and include jerk-like movements of the fetus. Tongue protrusion is coded and requires the fetus to open its mouth and stick its tongue out. Sucking involves a repetitive movement of the mouth and lips; it produces a drawing in of the mouth and lips producing a partial vacuum and is a repetitive movement.

Fetal breathing is a repetitive movement and it is described as an inward movement of the chest wall and a simultaneous outward movement of the abdominal wall.

Other codes: Fetal stretch and kicking

Fetal stretch describes the fetus extending its spinal cord and tilting its head backward for longer than 2 seconds. Finally, fetal kicking of the legs was coded when the legs were visible. Due to the nature of kicking, which results in general movements of the fetus, other movements were disregarded during coding as they are merely a result of the kicks and are involuntary.

The accuracy of the coding was frame-by-frame, which is 5 milliseconds. Both frequency (occurrence) and duration (how long each movement lasted) measures were computed for each variable.

Table 2a. Coding system developed to analyse fetal movements in utero. All original variables and

Variable Name	**Breakdown of Variables**	**Description**
Arm Movements	Starts/Stops	Any visible arm movements
Touch (hierarchal)	Own body	Fetus touches its own body with hand(s), everything apart from the face
	Face	Fetus touches its own face with hand(s)
	Hands-Uterus	Fetus touches the uterine wall with hand(s)
	Stop	Fetus lifts a hand off body/face/uterus wall and stops touching
Hands-crossed	Starts/Stops	Fetus makes two fists, which touch each other with the side of the palms
Arms-crossed	Starts/Stops	Arms are crossed over the body, also touching at the interception
Body turning	Starts/Stops	The whole body is turning away/towards the probe
Hiccup	Starts/Stops	quick jerk, starting in the upper torso
Yawning	Starts/Stops	Long opening of the mouth often accompanied by tilting the head backward
Mouth Movements	Starts/Stops	The mouth opens, lips part, and closes, lips back together
Tongue Movements (hierarchal)	Out	Tongue out of the mouth
	Moving in mouth	Only visible in 2D, the tongue is moving in mouth not coming out
	Stops	Tongue stops any movements
Sucking	Starts/Stops	Repetitive mouth, lip and tongue movements resulting in sucking

		movements
Breathing	Starts/Stops	Fetal breathing is described as an inward movement of the chest wall along with an outward movement of the abdominal wall
Stretching	Starts/Stops	Stretching, back bending of the head for more than 2s including straightening of the spinal chord
Hand movements (hierarchal)	Hand movements	General hand movements such as rotations or up and down movements of the wrist
	Fist	Hand and fingers move to form a fist
	Finger Movements	Single/Multiple finger(s) are moving independently
	Stops	All hand/finger movements stop
Face press	Starts/Stops	Face touches uterus wall with forehead or larger facial area
Kicking, Event		If legs are visible, rapid sudden movements

Table 2b. Combined Variables. Combined variables are computed creating a total number of frequencies and total duration in seconds for each computed variable.

Variable Name	Combination of	Description
General Movements	Arm Movements Head Movements	Both, ‘Arm Movements’ and ‘Head Movements’ are generally referred to as gross body movements.
Self-touch	Body Touch Face Touch	Both, ‘Body’ and ‘Face touch’, are forms of tactile self-stimulation.
External touch	Uterus touch Face press	Both, ‘Uterus touch’ and ‘Face press’ involve the fetus touching the uterine wall.
Inactivity/Resting	Arms-crossed Hands-crossed	Both, ‘Arms-crossed’ and ‘Hands-crossed’, are positions where the fetus is not moving, but inactive/ in a “resting” position instead.

The full dataset was anonymised prior to coding by assigning a number to the conditions. This means neither the main coder nor the reliability coder was aware of the condition at the time of the coding.

Reliability coding

10% of the data from each anonymised condition was reliability coded by a trained second coder who was naïve to the conditions.

Inter-rater reliabilities for frequency ranged from 75.44% to 98.33% with an average of 83.51% and Cohen’s kappas ranged from 0.74 to 0.98 with an average of .82. Inter-rater reliabilities for duration ranged from 75.14% to 99.77% with an average of 91.05% and Cohen’s kappas ranged from 0.74 to 1.00 with an average of .90.

Procedure

The experiment took place at the School of Psychology at the University of Dundee, in a semi-darkened room of the Developmental Neuropsychology laboratory. Participants were presented with a consent form, participant information sheet, and demographic questions prior the scan. Participants received no other incentive than a free scan and a copy of the scan on DVD for their participation.

In order to perform the ultrasound scan participants were required to lay on a scanning bed, using a pillow behind their head to achieve an optimal scanning posture. The experimenter was positioned next to the participant having the ultrasound system on a table. During the experiment the participant was asked to lay relaxed, not to touch or stroke the stomach, and remain silent during testing unless cued to speak in the live condition. Fetal wakefulness was assessed using ultrasound prior to the start of the experiment. If the fetus changed position it was tracked with the ultrasound in 4D, however, if the 4D acquisition was not possible the scan was continued in 2D.

During the scan, the experiment was videotaped in order to synchronise stimulus on- and offsets for later analysis.

The scan consisted of four within-subject conditions. Each condition followed a common pattern of 2 minutes' pre-stimulus baseline (no interaction), followed by 2 minutes of stimuli depending on condition (recorded voice, live voice, everyday noise, control), and 2 minutes of post-stimulus second baseline (no interaction) (see Figure 1.). Thus each condition lasted 6 minutes in total, resulting in a total scanning time of 24 min per participant. The order of the four conditions was randomized and counterbalanced across the participants. Overall time required time for this experiment was approximately 50 minutes and participants were allowed to withdraw at any point of the experiment.

The Conditions

Everyday Noise Condition

The everyday noise stimulus was played back at an intensity of 75dB, as measured by “Precision Gold” sound-level meter (model N05CC), to the maternal abdomen using a loudspeaker placed 10 cm away from the maternal abdomen in order to achieve the optimal frequency levels at the maternal abdomen. The road sound was played back to the maternal abdomen using a loudspeaker set to 75dB, representing daytime urban environments as measured by the sound-level meter. 75 dB is the common intensity of a passing car, it is just above a quiet conversation or the sound of air conditioning (60dB) and below a passing truck, dishwasher, or average factory sounds (80dB, which is twice as loud as 70dB) (Temple University Department of Civil/Environmental Engineering and Federal agency review of selected airport noise analysis issues, federal interagency committee on noise, 1992).

Maternal Live voice condition

In the maternal live voice condition, the participant was asked to begin their monologue after 2 minutes when being prompted with a nonverbal cue (hand sign) by the supervisor as a second experimenter. After 2 minutes another nonverbal cue was given as a stop sign. This condition was a continuation from the previous monologue used for the recording. The mothers were given the same pre-prepared questions and continued answering them live, working their way through them in random order or just picking one of them as the main topic for their monologue, for 2 minutes (see Appendix 4 for questions).

Maternal Recorded voice condition

Mothers’ voice was recorded prior to the ultrasound scan. Mothers were asked to hold and record a 2-minute monologue using an iPhone 5S. In order to facilitate the monologue, mothers familiarised themselves with prepared questions (see Appendix 4), which prevented occurrences of longer pauses during the recording. The recording was saved to be played back during the experiment at the recorded voice condition. The frequency of the stimulus was set to 96 dB (Jacquet et al., 2009), which was monitored by a “Precision Gold” sound-level meter (model N05CC) held close to the surface of the maternal abdomen.

Control Condition

The control condition did not involve any stimulation. The mother lay motionless on the scanning bed while the ultrasound was performed. The room was in complete silence during the control condition, with neither experimenters nor the mother speaking. This set up was also used for both (pre- and post-stimuli) baselines.

Questionnaires

Following the scan, participants were asked to complete the AMAS (Condon, 1993) and the BDI (Beck et al., 1961) questionnaires.

Results

All coded variables and combined variables were analysed. The reported results will include all significant results ($p < .05$) as well as tendencies ($p < .10 \geq .05$). Bonferroni corrections were applied for all post-hoc analyses. Although each stimulation/experimental condition lasted 2 minutes in total, this analysis attempted to examine the responses at various time intervals to further explore the evolvement of the responses over time. Focusing only on the whole 2-minute interval would disregard many sensitive findings which occur throughout the 2-minute period including the initial response and possible habituation to the stimulation. The 2-minute interval is of course included in the analysis, as significant results from this section should represent the strongest results of the conditions.

In previous studies, the most common intervals chosen for the analysis of fetal responses focus primarily on the first 1-2 minutes of stimulation

(Kisilevsky et al., 1992; Shahidullah et al., 2007). Thus the analysis will include both the first minute of stimulation (0-60s), the succeeding minute (60-120s) and the entire 2 minutes of stimulation (0-120s).

Whether fetal responses start even earlier than the averaged 60 or 120 seconds, is unknown. Possible transient, immediate responses during the first 10-15 seconds of the stimulation are likely to be averaged out by a larger time interval analysis. Thus both 0-10 seconds and 0-15 seconds were included in the analysis. Furthermore, the experimental conditions were split into 30-second intervals in order to explore the evolvement of the behaviour throughout the conditions producing the following time intervals: 0-30 seconds, 30-60 seconds, 60-90 seconds, and 90-120 seconds.

The breakdown of 30 second intervals allows us to examine the responses in smaller chunks over the course of the condition as previous research suggests that the fetus motor movements habituate quicker to external stimulation compared to fetal cardiac responses (Lecanuet, Busnel, & Granier-Deferre, 1988; Lecanuet, Cohen, Granier-Deferre, & Busnel, 1983; Lecanuet, Cohen, Le Houezec, Busnel, & Granier-Deferre, 1986). For an overview of the time interval breakdowns see Figure 2b.

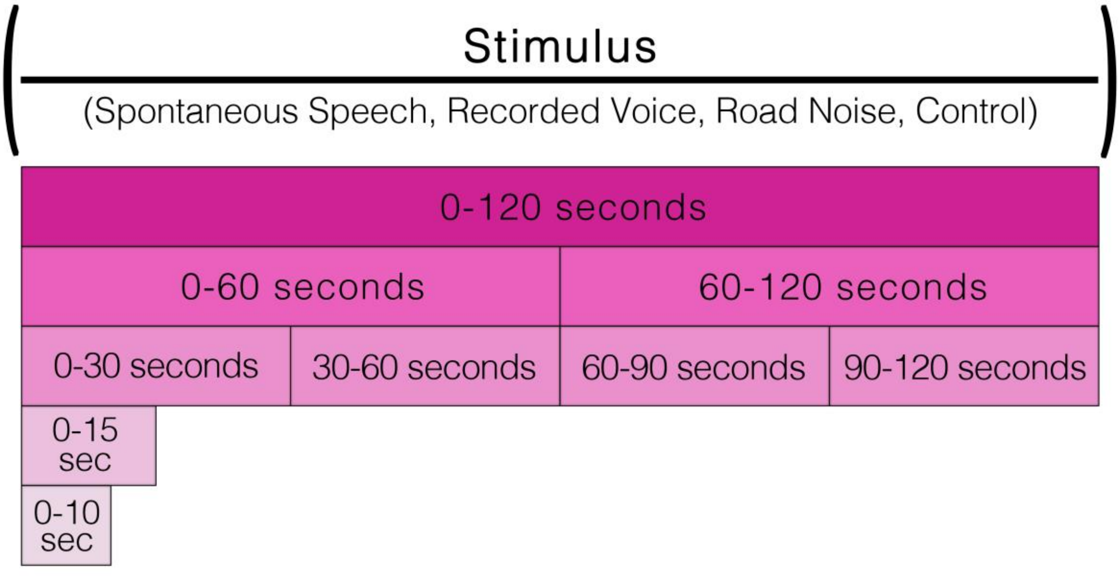

Figure 2b. Figure showing a breakdown of the created time sections for the interval analysis of the stimulation condition (0-120s, 0-60s, 60-120s, 0-30s, 30-60s, 60-90s, 90-120s, 0-15s, 0-10s).

Due to the length of analysis and the focus of the thesis, maternal mental health (BDI) and the attachment data, although analysed, are not reported in the chapter.

0-10s Interval analysis

Repeated-measures ANOVA Condition: 'Face press' Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the 'Face press' between the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results showed a significant difference between Conditions F (2.51, 72.70) = 3.00, p = .045, η_p^2 = .09. Examination of the means suggests that fetuses touched the uterine wall with their face differently between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.21, p = .030, η_p^2 = .15. However, this finding was qualified by the significant cubic trend, F (1, 29) = 6.90, p = .014, η_p^2 = .19. Overall, there is a linear increase produced by the means from 'Control' (M = 1.20) to the 'Noise' condition (M = 2.80). However, the 'Recording' condition has a somewhat lower mean (M = 1.40) than the 'Live' condition (M = 1.80) producing the cubic trend.

Post-hoc analysis showed a trend between 'Noise' and 'Control', with fetuses increasing 'Face press' frequency in the 'Noise' (M = 2.80) condition compared to 'Control' (M = 1.20, p = .053) (see Figure 2.1). No further effects were found. The means and standard errors can be examined in Table 2.1.

Table 2.1. Means and standard errors (SE) on the frequency of fetuses facial touch of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	1.20	1.80	1.40	2.80
SE	0.45	0.51	0.47	0.56

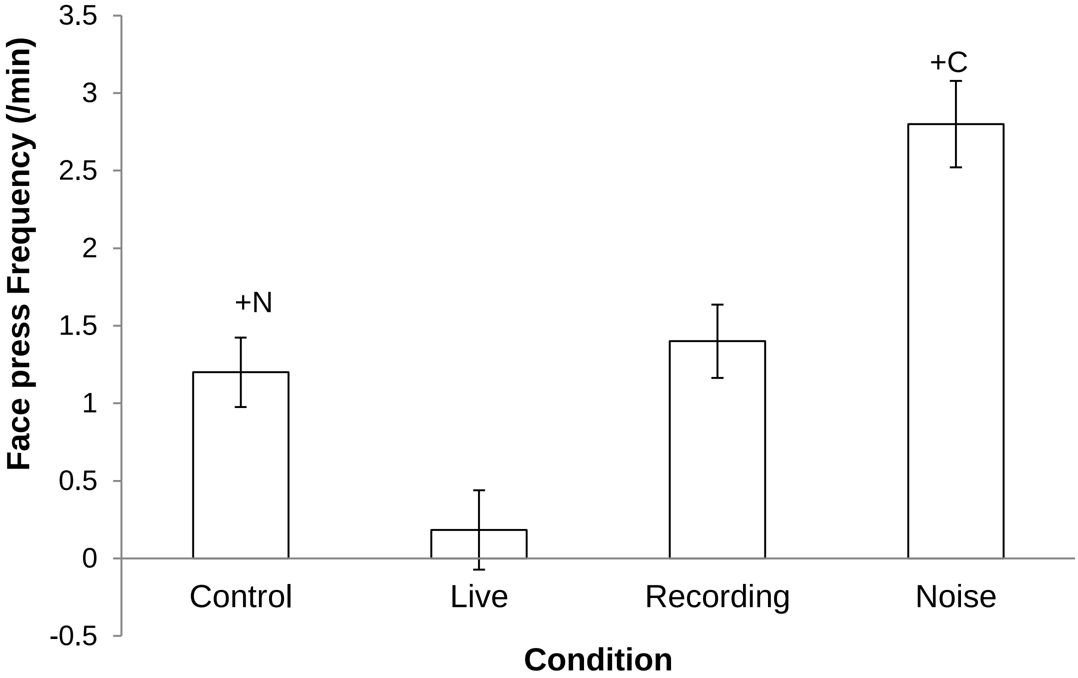

Figure 2.1. Average 'Face press' frequency (per minute) including standard errors for each condition (.05 ≥+< .10).

Repeated-measures ANOVA Condition: 'Face press' Duration

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in duration of the 'Face press' between the four Conditions (Control, Live, Recording, Noise). Results indicate that there was a significant difference in 'Face press' duration between the four Conditions F (2.51, 72.70) = 3.00, p = .045, η_p^2 = .09. Examination of these means suggests that the duration of fetuses touching the uterine wall with their face differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.21, p = .030, η_p^2 = .15. However, this finding was qualified by the significant cubic trend, F (1, 29) = 6.90, p = .014, η_p^2 = .19. Overall, there is a linear increase produced by the means from ‘Control’ (M = 20.00) to the ‘Noise’ condition (M = 46.67). However, the ‘Recording’ condition has a somewhat lower mean (M = 23.33) than the ‘Live’ condition (M = 30.00) producing the cubic trend.

Post-hoc analysis showed a trend between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ duration in the ‘Noise’ (M = 46.67) condition compared to ‘Control’ (M = 20.00, *p* = .053) (see Figure 2.2). No further effects were found. The means and standard errors can be examined in Table 2.2.

Table 2.2. Means and standard errors (SE) on the duration of fetuses ‘Face press’ against the uterus across conditions.

	Control	Live	Recording	Noise
Mean	20.00	30.00	23.33	46.67
SE	7.43	8.51	7.85	9.26

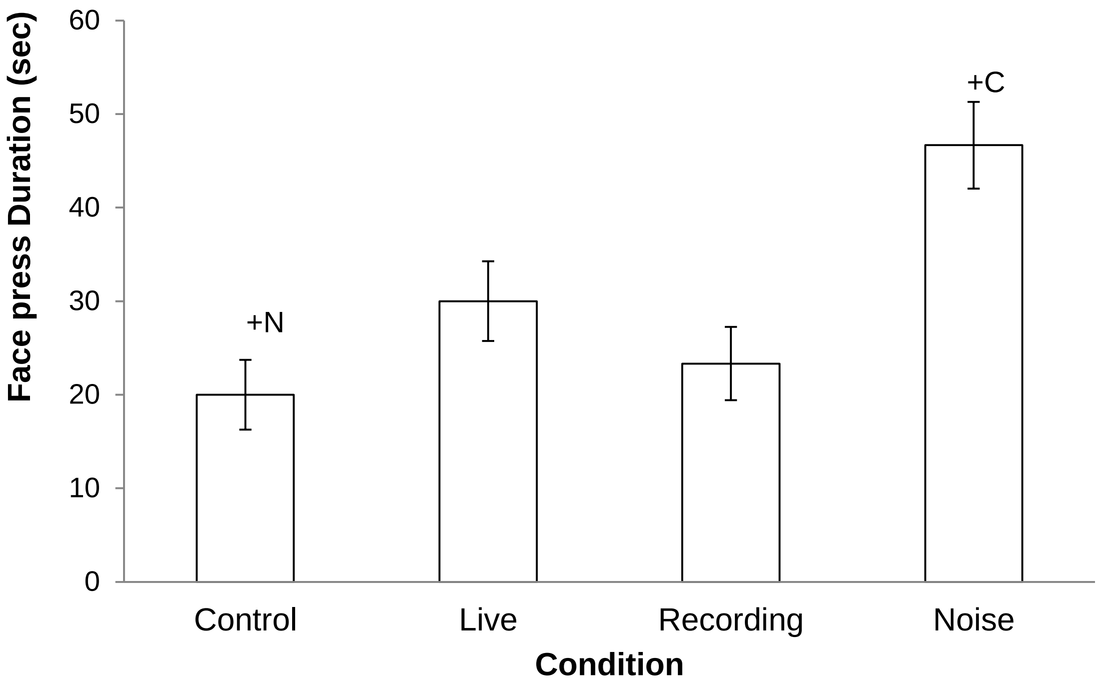

Figure 2.2. Average ‘Face press’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Arm Movement' Frequency*

A mixed design ANOVA was conducted to assess differences in 'Arm movement' frequency and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effects of Condition F (3, 84) = 0.96, p = .414, η_p^2 = .03, and GA F (1, 28) = 1.21, p = .281, η_p^2 = .04. However, a significant interaction between Condition and GA, F (3, 84) = 2.82, p = .044, η_p^2 = .09, showing that 'Arm movement' frequency is dependent on Condition and GA, was found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 28) = 7.30, p = .012, η_p^2 = .21.

Post-hoc analysis of the interaction showed that in the 'Live' condition younger fetuses (M = 5.08) tend to increase 'Arm movements compared to older fetuses (M = 1.77, p = .081). The same tendency was observed in the 'Recording' condition (younger fetuses: M = 5.54; older fetuses: 2.47; p = .086) (see Figures 2.3 and 2.4). No further effects were found. The means and standard errors can be examined in Table 2.3.

Table 2.3. Means and standard errors (SE) of fetuses 'Arm movement' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.58	0.70	2.56	0.61		
Control	2.31	1.04	2.12	0.91	2.20	0.69
Live	5.08	1.38	1.77	1.21	3.20	0.92
Recording	5.54	1.30	2.47	1.14	3.80	0.86
Noise	1.39	1.34	3.88	1.17	2.80	0.89

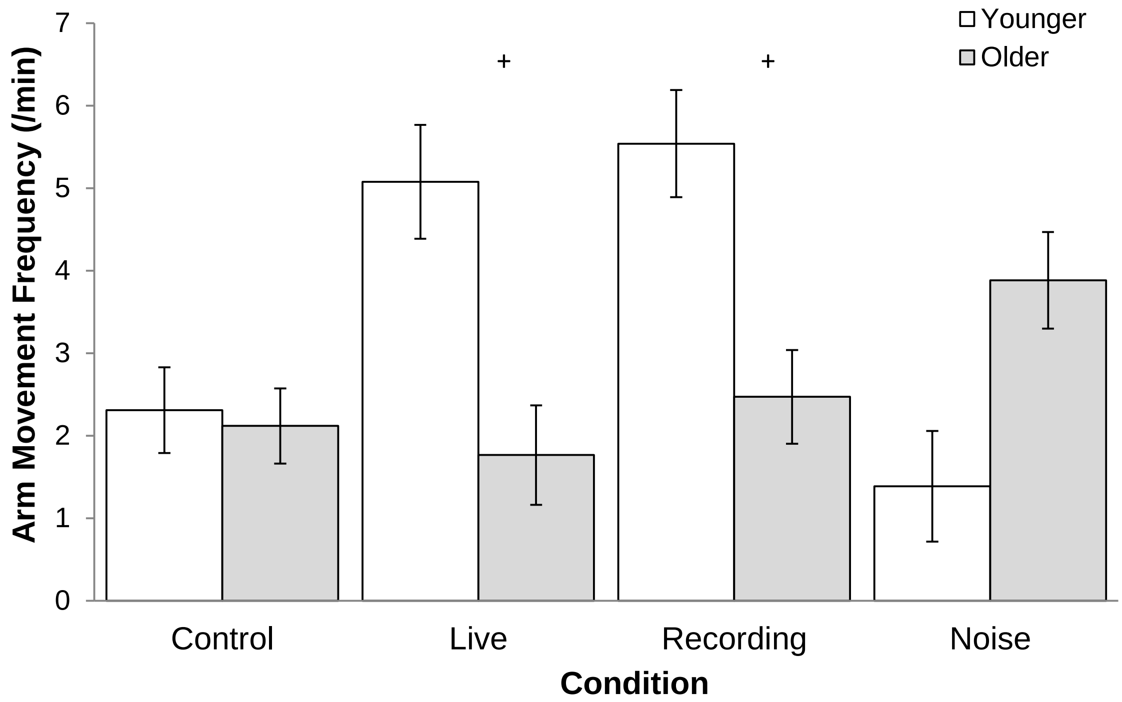

Figure 2.3. Average ‘Arm movement’ frequency (per minute) including standard errors for all four conditions across GA (younger and older fetuses) (.05 ≥+≤ .10).

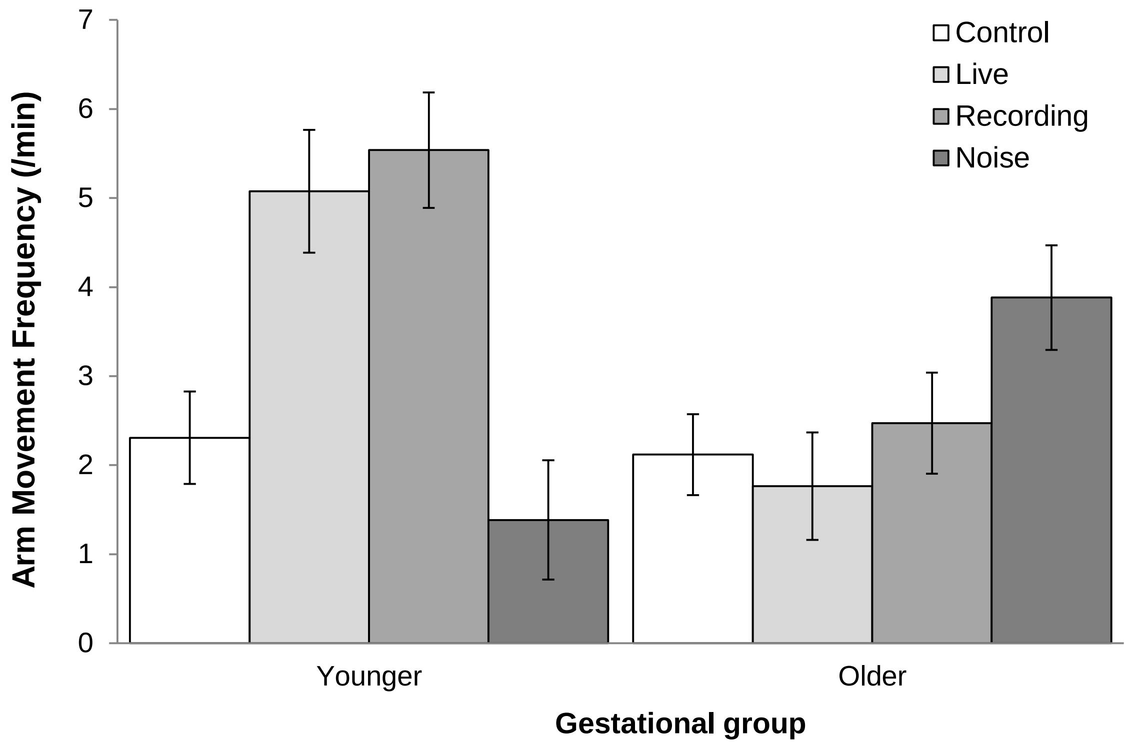

Figure 2.4. Average ‘Arm Movement’ frequency (per minute) including

standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: 'Uterus touch' Frequency*

A mixed design ANOVA was conducted to assess differences in 'Uterus touch' frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a tendency for main effect of Condition *F* (3, 84) = 2.42, $p = .072$, $\eta_p^2 = .08$ regardless of GA, no significant main effect of GA *F* (1, 28) = 1.54, $p = .225$, $\eta_p^2 = .05$ and a significant interaction between Condition and GA, *F* (3, 84) = 3.96, $p = .011$, $\eta_p^2 = .12$. In support of this polynomial contrasts of the main effect show a significant quadratic trend of Condition and GA *F* (1, 28) = 5.20, $p = .030$, $\eta_p^2 = .16$, reflecting an increase from 'Control' (M = 0.87) over 'Live' (M = 1.56) to 'Recording' (M = 2.04) followed by a drop to 'Noise' (M = 0.71). Polynomial contrasts of the interaction indicated a significant linear trend *F* (1, 28) = 8.46, $p = .007$, $\eta_p^2 = .23$.

Post-hoc analysis of the main effect showed a tendency between 'Recording' and 'Noise' conditions ($p = .089$), with more uterus touch displayed in the 'Recording' condition (M = 2.04) compared to 'Noise' (M = 0.71) (see Figure 2.5).

Post-hoc analysis of the interaction showed that younger fetuses (M = 2.77) touch the uterus significantly ($p = .008$) more in 'Live' compared to older fetuses (M = 0.35). A tendency can be observed between age groups in 'Noise', with younger fetuses (M = 0.00) displaying a decrease in touch frequency compared to older fetuses (M = 1.41, $p = .064$). Younger fetuses increased 'Uterus touch' significantly during 'Live' ($p = .022$) and 'Recording' ($p = .034$) stimulations compared to 'Noise' (see Figures 2.6 and 2.7). No further effects were found. The means and standard errors can be examined in Table 2.4.

Table 2.4. Means and standard errors (SE) of fetuses 'Uterus touch' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.62	0.39	0.97	0.32		
Control	1.39	0.57	0.35	0.50	0.87	0.38
Live	2.77	0.64	0.35	0.56	1.56	0.43
Recording	2.31	0.81	1.77	0.71	2.04	0.54
Noise	0.00	0.55	1.41	0.48	0.71	0.37

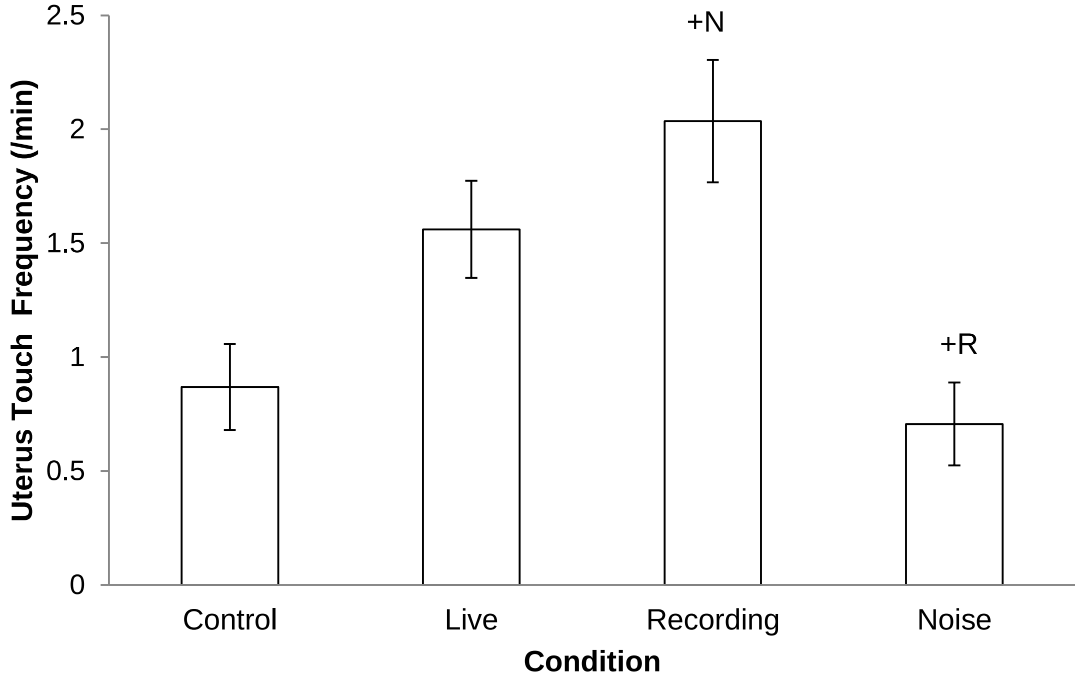

Figure 2.5. Average 'Uterus touch' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

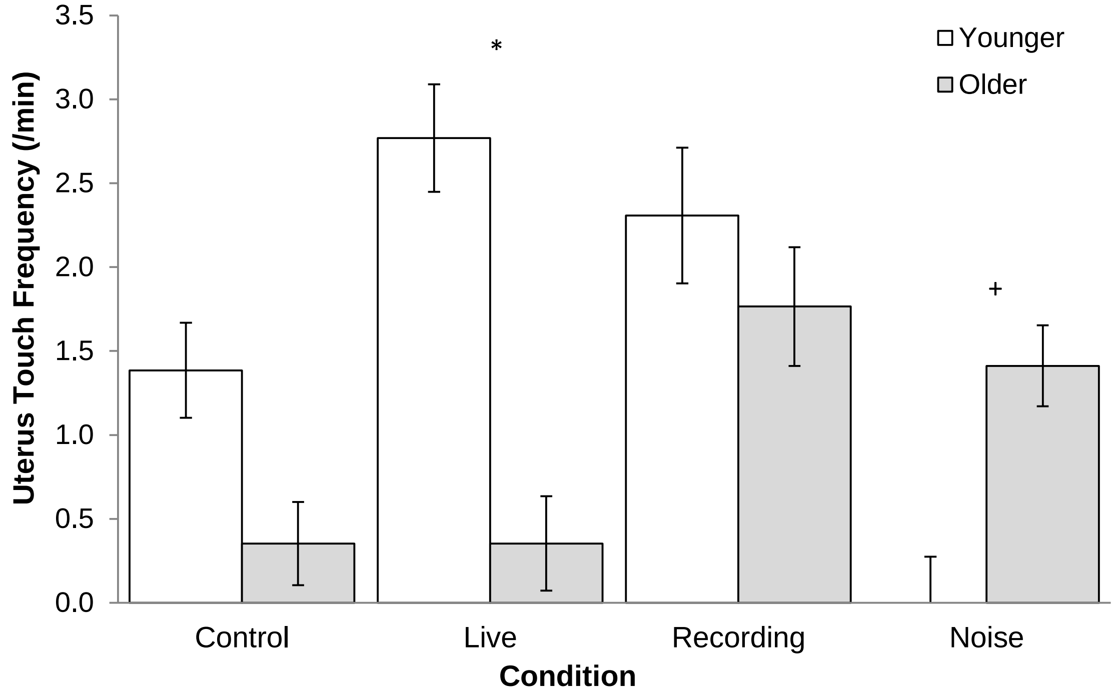

Figure 2.6. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

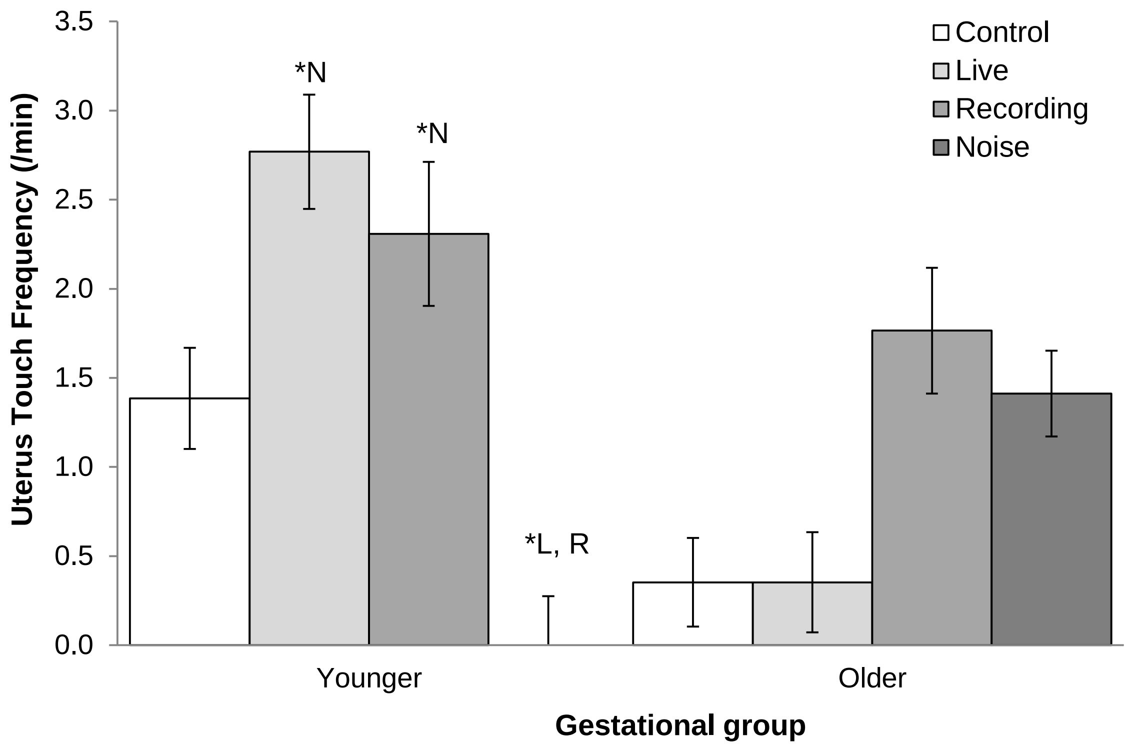

Figure 2.7. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

*Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘Uterus touch’ duration and GA across the four Conditions (Control, Live, Recording, Noise). No significant main effect of Condition $F(3, 84) = 1.79$, $p = .155$, $\eta_p^2 = .06$, or GA $F(1, 28) = 1.09$, $p = .305$, $\eta_p^2 = .04$, was found. Results showed the interaction between Condition and GA revealed a tendency, $F(3, 84) = 2.71$, $p = .050$, $\eta_p^2 = .10$. In support of this polynomial contrasts indicated a linear trend $F(1, 28) = 6.54$, $p = .016$, $\eta_p^2 = .19$ of Condition and GA.

Post-hoc analysis of the interaction showed that younger fetuses (M = 32.89) tend to touch the uterus longer in ‘Live’ compared to older fetuses (M = 5.88, $p = .050$). A further tendency was observed between age groups in ‘Noise’, with younger fetuses (M = 0.00) touching less compared to older fetuses (M = 19.82, $p = .081$). Younger fetuses displayed a tendency towards a longer ‘Uterus touch’ in ‘Recording’ (M = 34.02) compared to ‘Noise’ (M = 0.00, $p = .057$) (see Figures 2.8 and 2.9). No further effects were found. The means and standard errors can be examined in Table 2.5.

Table 2.5. Means and standard errors (SE) of fetuses ‘Uterus touch’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	22.49	6.17	13.92	5.40		
Control	23.08	9.45	5.88	8.26	14.48	6.28
Live	32.89	9.94	5.88	8.69	19.38	6.60
Recording	34.02	12.33	24.09	10.78	29.05	8.19
Noise	0.00	8.24	19.82	7.20	9.91	5.47

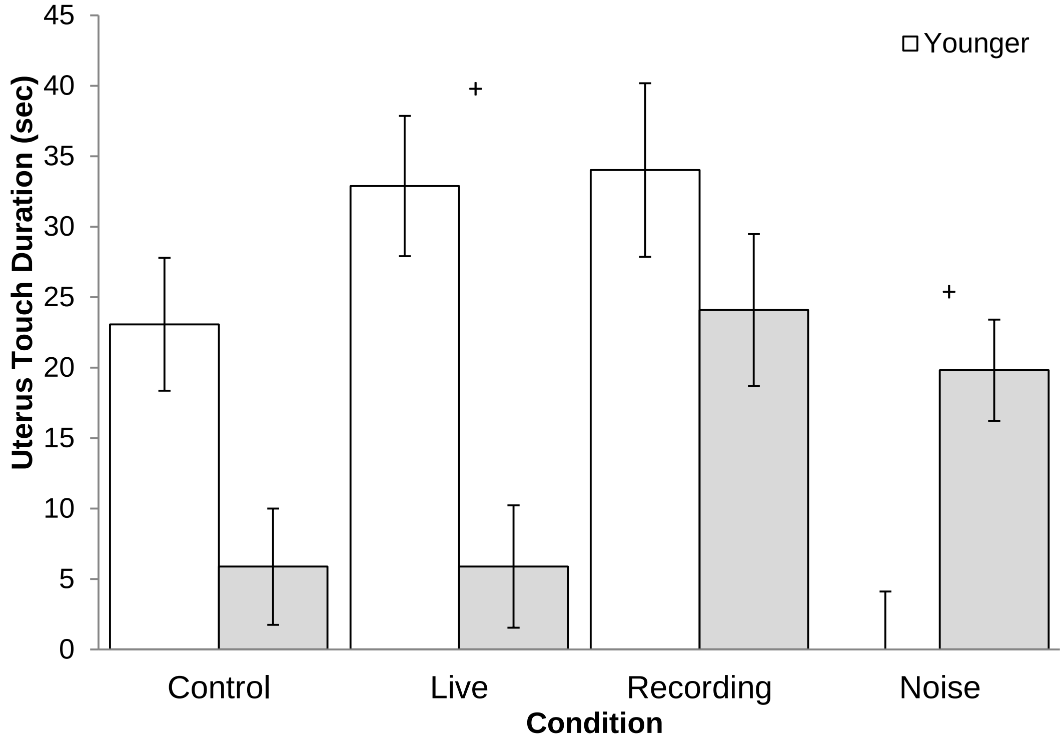

Figure 2.8. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions across GA (younger and older fetuses) (.05 ≥+≤ .10).

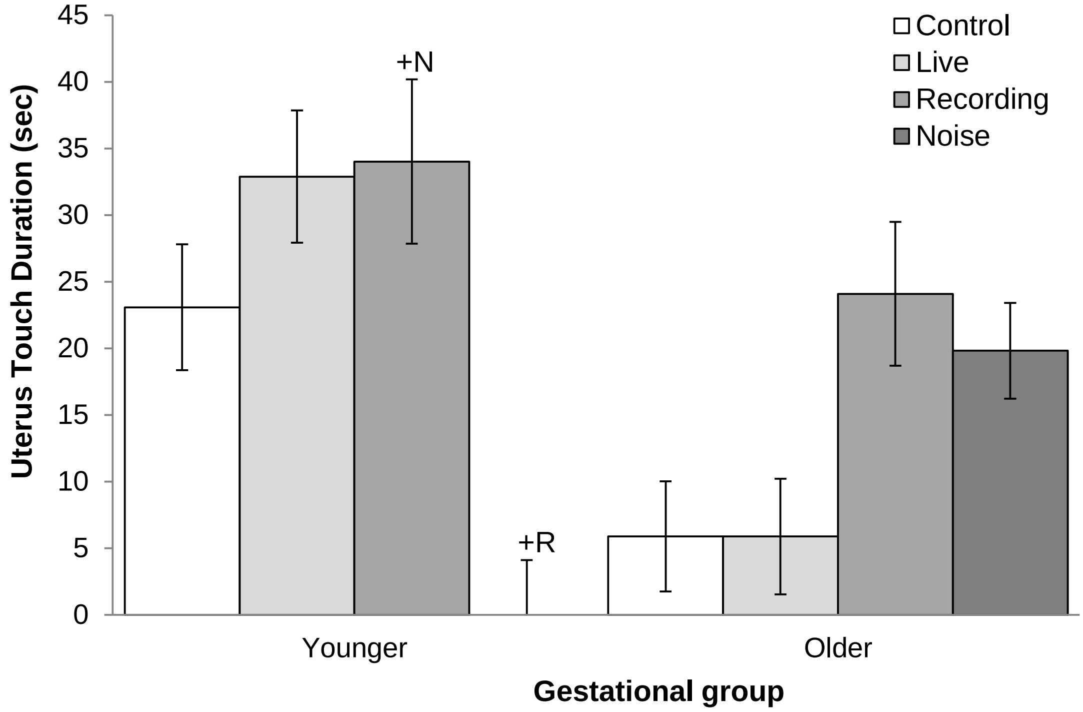

Figure 2.9. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Face press' Frequency*

A mixed design ANOVA was conducted to assess differences in 'Face press' frequency and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. The Condition main effect indicates a trend, F (2.24, 70.89) = 2.98, p = .052, η_p^2 = .10. No significant main effect of GA F (1, 28) = 0.21, p = .651, η_p^2 = .01, or an interaction F (2.24, 70.89) = 2.00, p = .139, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 4.60, p = .041, η_p^2 = .14, which is qualified by a significant cubic trend F (1, 28) = 6.05, p = .020, η_p^2 = .18, of Condition, reflecting an increase from 'Control' (M = 1.28) to 'Noise' (M = 2.80), however the 'Recording' condition has a somewhat lower mean (M = 1.34) compared to 'Live' (M = 1.70) producing the cubic trend.

Post-hoc analysis of the Condition main effect revealed a tendency between 'Control' and 'Noise' with a higher frequency of 'Face press' in 'Noise' (M = 2.80) compared to 'Control' (M = 1.28, p = .080) (see Figure 2.10). No further effects were found. The means and standard errors can be examined in Table 2.6.

Table 2.6. Means and standard errors (SE) of fetuses 'Face press' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.62	0.54	1.94	0.47		
Control	1.85	0.67	0.71	0.59	1.28	0.45
Live	0.92	0.76	2.47	0.66	1.70	0.50
Recording	0.92	0.72	1.77	0.63	1.34	0.48
Noise	2.77	0.86	2.82	0.75	2.80	0.57

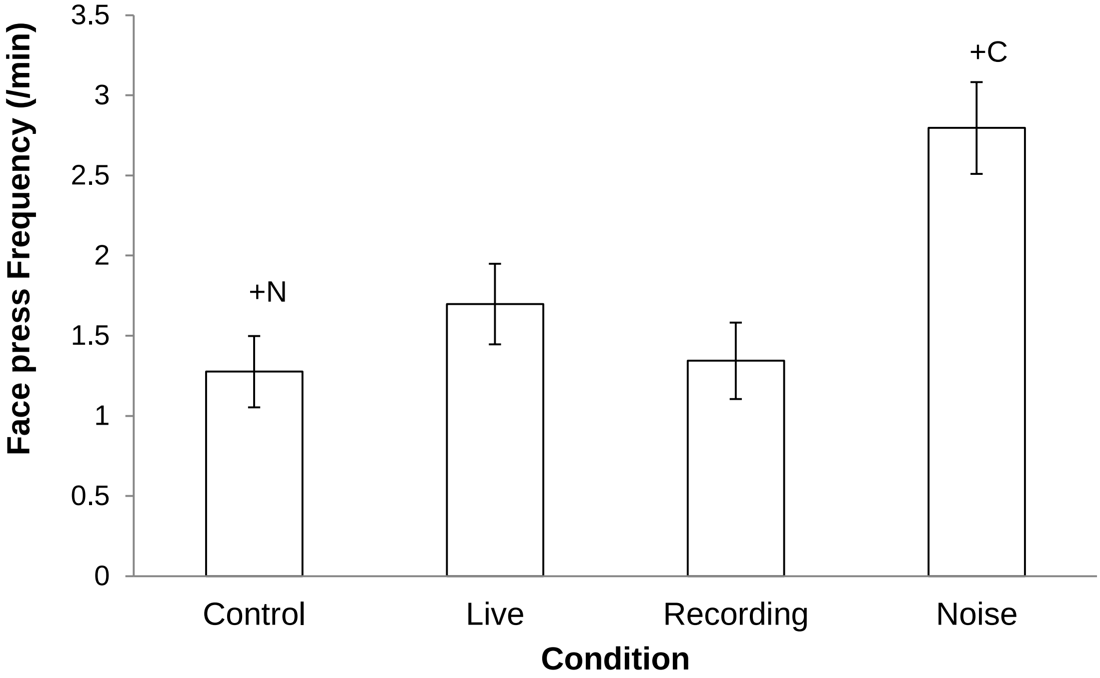

Figure 2.10. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘Face press’ duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. The Condition main effect indicates a trend, F (2.24, 62.74) = 2.98, p = .052, η_p^2 = .10. No significant main effect of GA F (1, 28) = 0.21, p = .651, η_p^2 = .01, or an interaction F (2.24, 62.74) = 2.00, p = .139, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 4.60, p = .041, η_p^2 = .14, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 28) = 6.05, p = .020, η_p^2 = .18. Overall, there is a linear increase produced by the means from ‘Control’ (M = 21.27) to the ‘Noise’ condition (M = 46.61). However, the ‘Recording’ condition has a somewhat lower mean (M = 22.40) than the ‘Live’ condition (M = 28.28) producing the cubic trend.

Post-hoc analysis of the main effect of condition showed a tendency between ‘Control’ and ‘Noise’ with a longer duration of ‘Face press’ in ‘Noise’ (M = 46.61)

compared to ‘Control’ (M = 21.27, *p* = .080) (see Figure 2.11). No further effects were found. The means and standard errors can be examined in Table 2.7.

Table 2.7. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	26.92	8.93	32.35	7.81		
Control	30.77	11.16	11.77	9.76	21.27	7.41
Live	15.39	12.63	41.17	11.05	28.28	8.39
Recording	15.39	11.98	29.41	10.47	22.40	7.96
Noise	46.15	14.32	47.06	12.52	46.61	9.51

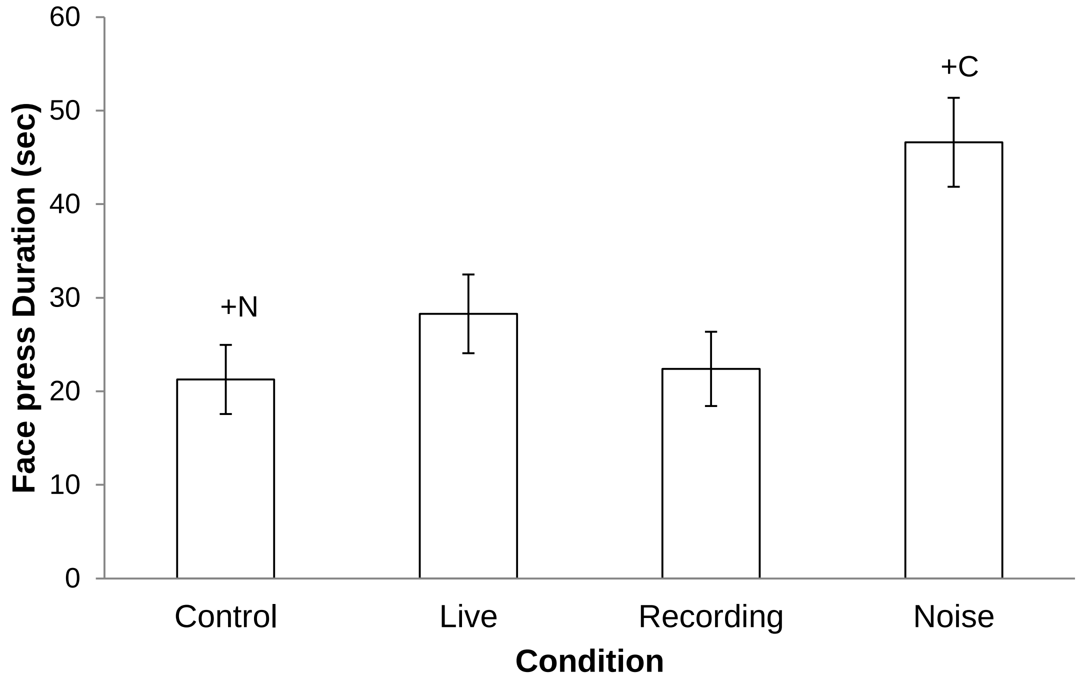

Figure 2.11. Average ‘Face press’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

0-10 Interval analysis combined

*Mixed-design ANOVA Condition*GA: ‘General Movement’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘General movement’ frequency and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effects of Condition F (3, 84) = 1.42, p = .243, η_p^2 = .05, and GA F (1, 28) = 1.30, p = .264, η_p^2 = .04. However, a marginally significant interaction between Condition and GA, F (3, 84) = 2.37, p = .076, η_p^2 = .08, was found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 28) = 5.26, p = .030, η_p^2 = .16.

Post-hoc analysis of the interaction showed no further results (see Figures 2.12 and 2.13). No further effects were found. The means and standard errors can be examined in Table 2.8.

Table 2.8. Means and standard errors (SE) of fetuses ‘General movement’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	5.77	1.01	4.24	0.89		
Control	4.15	1.57	2.82	1.38	3.49	1.05
Live	8.77	2.05	4.59	1.79	6.68	1.36
Recording	7.85	2.20	3.53	1.92	5.69	1.46
Noise	2.31	1.64	6.00	1.43	4.15	1.09

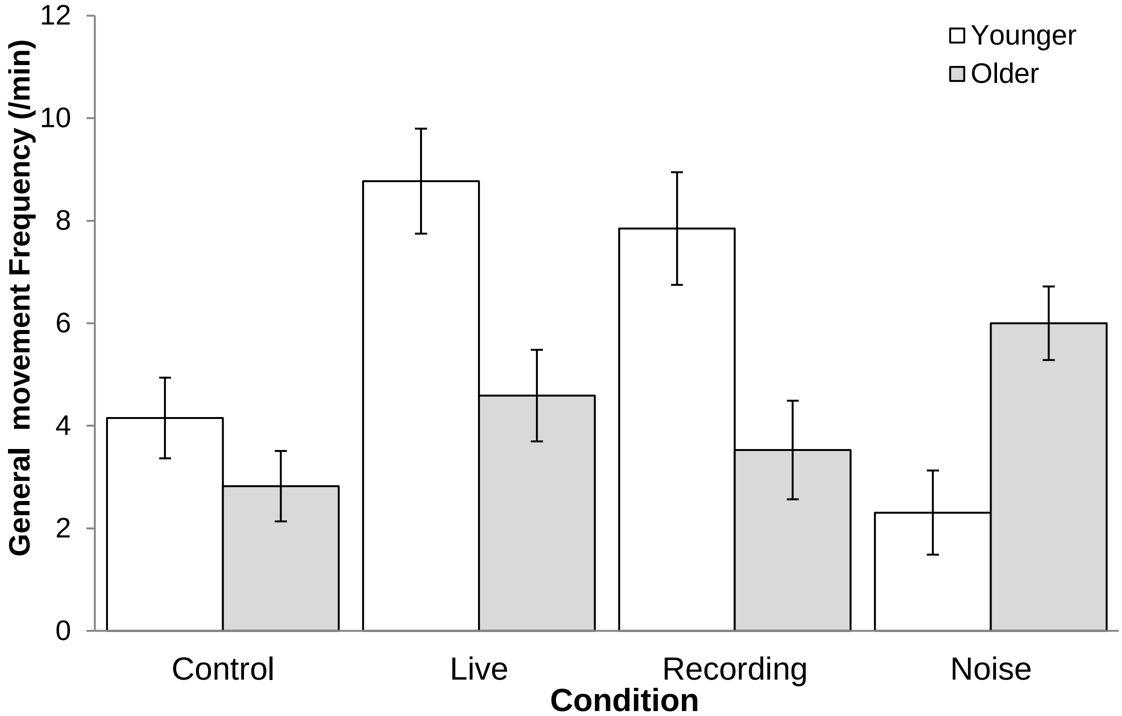

Figure 2.12. Average ‘General movement’ frequency (per minute) including standard errors for all four conditions across GA (younger and older fetuses).

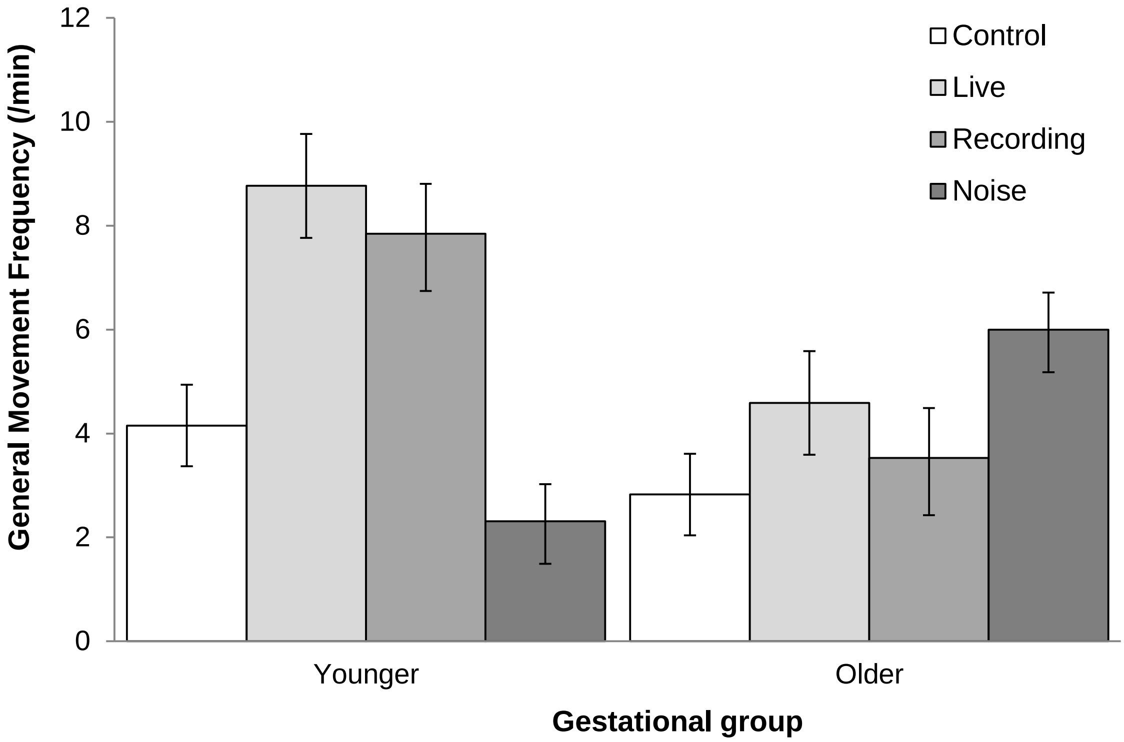

Figure 2.13. Average ‘General movement’ frequency (per minute) including

standard errors for all four conditions between gestational ages (younger and older fetuses)

0-15 Interval analysis

Repeated-measures ANOVA Condition: ‘Face press’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). As the assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results indicate that there was a trend in ‘Face press’ frequency between the four Conditions F (2.53, 73.40) = 2.89, p = .050, η_p^2 = .09. errors. Examination of these means suggests that fetuses ‘Face press’ frequency changed depending on Condition. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 4.62, p = .040, η_p^2 = .14. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.37, p = .007, η_p^2 = .22. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.80) to the ‘Noise’ condition (M = 1.87). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.93) than the ‘Live’ condition (M = 1.33) producing the cubic trend. Post-hoc analysis showed a trend between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ frequency in the ‘Noise’ (M = 1.87) condition compared to ‘Control’ (M = 0.80, p = .053) (see Figure 2.14). No further effects were found. The means and standard errors can be examined in Table 2.9.

Table 2.9. Means and standard errors (SE) on the frequency of fetuses ‘Face press’ of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	0.80	1.33	0.93	1.87
SE	0.30	0.35	0.31	0.37

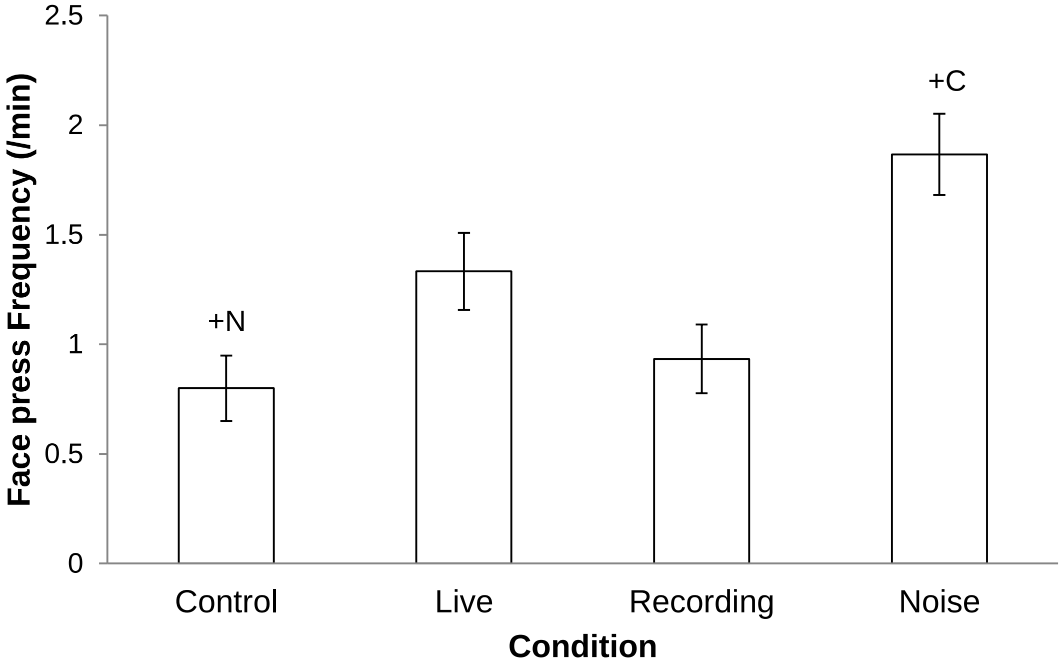

Figure 2.14. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in duration of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). Results indicate that there was a significant difference in ‘Face press’ duration between the four Conditions F (2.50, 72.39) = 3.00, p = .045, η_p^2 = .09. Examination of these means suggests that ‘Face press’ duration differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.06, p = .032, η_p^2 = .15. However, this finding was qualified by the significant cubic trend, F (1, 29) = 7.73, p = .009, η_p^2 = .21. Overall, there is a linear increase produced by the means from ‘Control’ (M = 20.00) to the ‘Noise’ condition (M = 46.67). However, the ‘Recording’ condition has a somewhat lower mean (M = 23.34) than the ‘Live’ condition (M = 30.87) producing the cubic trend.

Post-hoc analysis showed a trend between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ duration in the ‘Noise’ (M = 46.67) condition compared to 'Control' (M = 20.00, p = .053) (see Figure 2.15). No further effects were found. The means and standard errors can be examined in Table 2.10.

Table 2.10. Means and standard errors (SE) on the duration of fetuses facial touch of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	20.00	30.87	23.33	46.67
SE	7.43	8.45	7.85	9.26

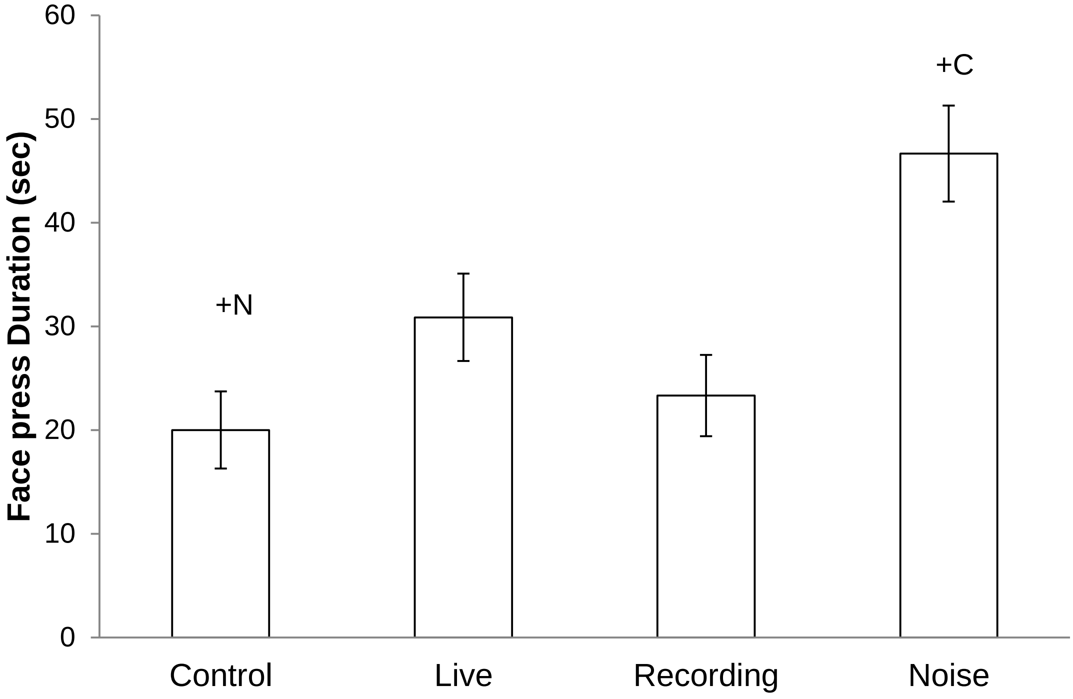

Figure 2.15. Average 'Face press' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Arm Movement' Frequency*

A mixed design ANOVA was conducted to assess differences in 'Arm movement' frequency and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results indicated a significant interaction between Condition and GA, F (3, 83.90) = 4.98, p = .003, η_p^2 = .15. Furthermore, a

tendency of the main effect *F* (3, 83.90) = 2.22, *p* = .092, η_p^2 = .07 of Condition, as well as a trend in GA *F* (1, 28) = 3.64, *p* = .067, η_p^2 = .12, were found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition *F* (1, 28) = 7.47, *p* = .011, η_p^2 = .21, reflecting an increase from 'Control' (M = 2.44) to 'Live' (M = 4.33), and a decrease from 'Live' over 'Recording' (M = 3.83) to 'Noise' (M = 2.11). Further significant quadratic trends were found for the interaction *F* (1, 28) = 14.47, *p* = .001, η_p^2 = .34.
Post-hoc analysis of the main effect of Condition showed a tendency (*p* = .132) no tendency here for increased frequency of 'Arm movements' in 'Live' compared to the 'Noise' condition (see Figure 2.16). The tendency of the GA main effect showed that younger fetuses (M = 4.00) move more (*p* = .067) compared to older fetuses (M = 2.35) (see Figure 2.19). Post-hoc analysis of the interaction showed that younger fetuses display significantly more 'Arm movements' in 'Live' (M = 6.77, *p* = .012), 'Recording' (M = 5.54, *p* = .026), and marginally significant in 'Noise' (M = .092, *p* = .085) compared to older fetuses ('Live': M = 1.88, 'Recording': M = 2.12, 'Noise': M = 3.29). A significant increase in 'Arm movements' was found between 'Live' (M = 6.77) and 'Noise' for younger fetuses (M = 0.92, *p* = .001). Further tendencies between 'Live' (M = 6.77) and 'Control' (M = 2.77, *p* = .074) and 'Recording' (M = 5.54) and 'Noise' were observed (M = 0.92, *p* = .066) (see Figures 2.17 and 2.18). No further effects were found. The means and standard errors can be examined in Table 2.11.

Table 2.11. Means and standard errors (SE) of fetuses ‘Arm movement’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	4.00	0.65	2.35	0.57		
Control	2.77	1.05	2.12	0.92	2.44	0.70
Live	6.77	1.38	1.88	1.20	4.33	0.91
Recording	5.54	1.10	2.12	0.96	3.83	0.73
Noise	0.92	1.00	3.29	0.88	2.11	0.67

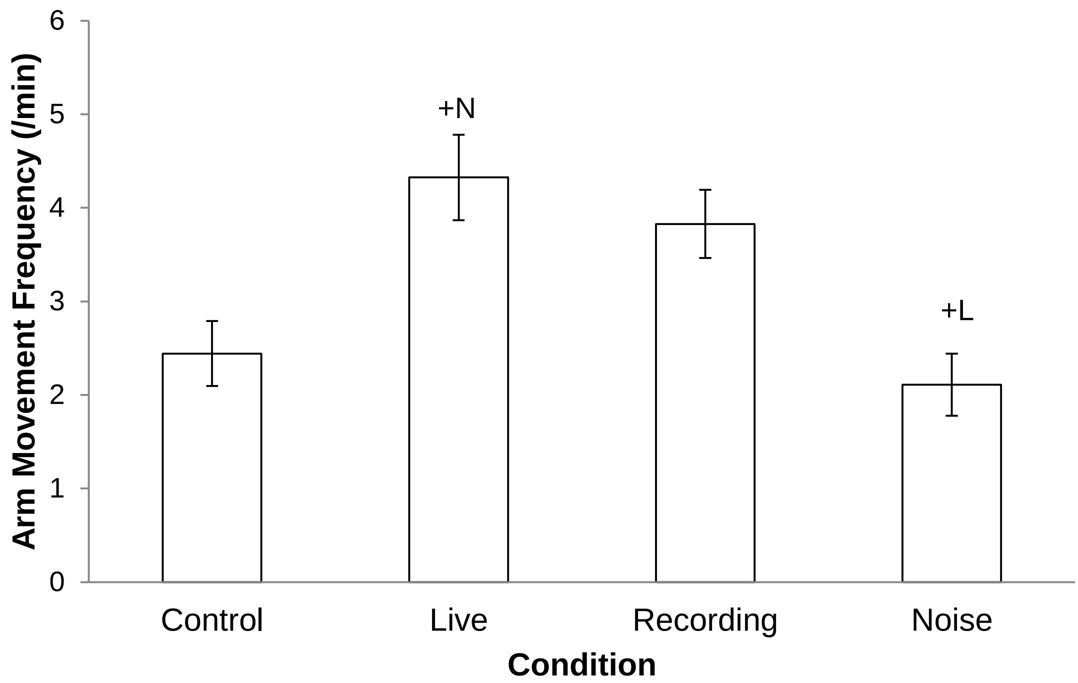

Figure 2.16. Average ‘Arm movement’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

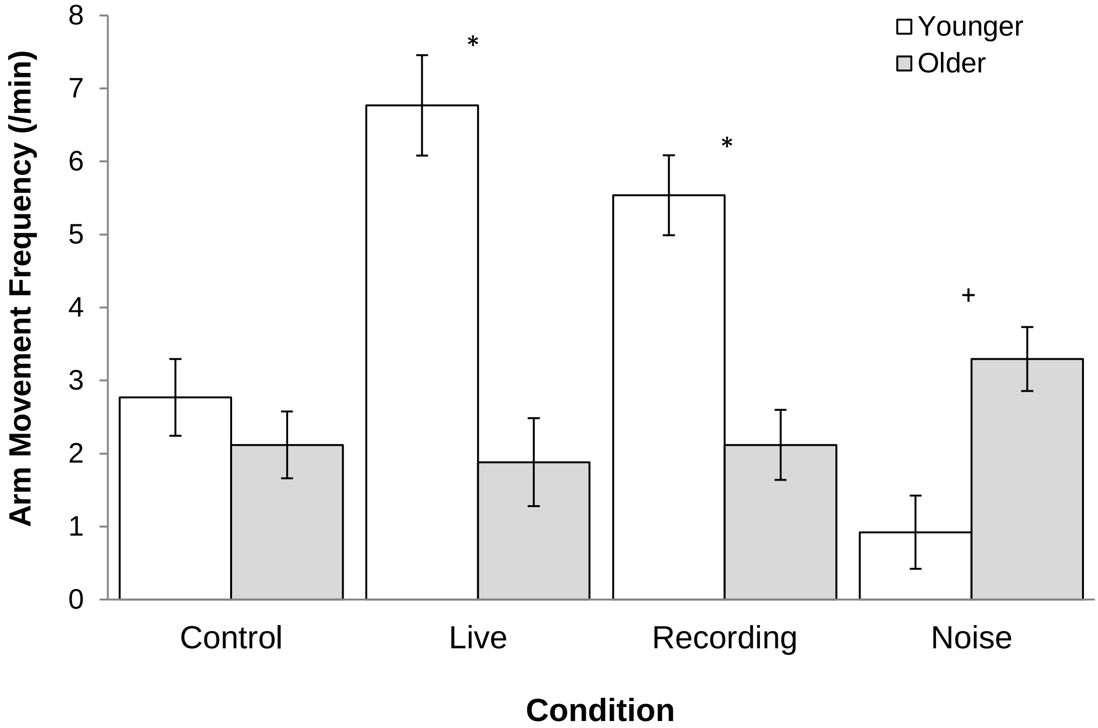

Figure 2.17. Average ‘Arm movement’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

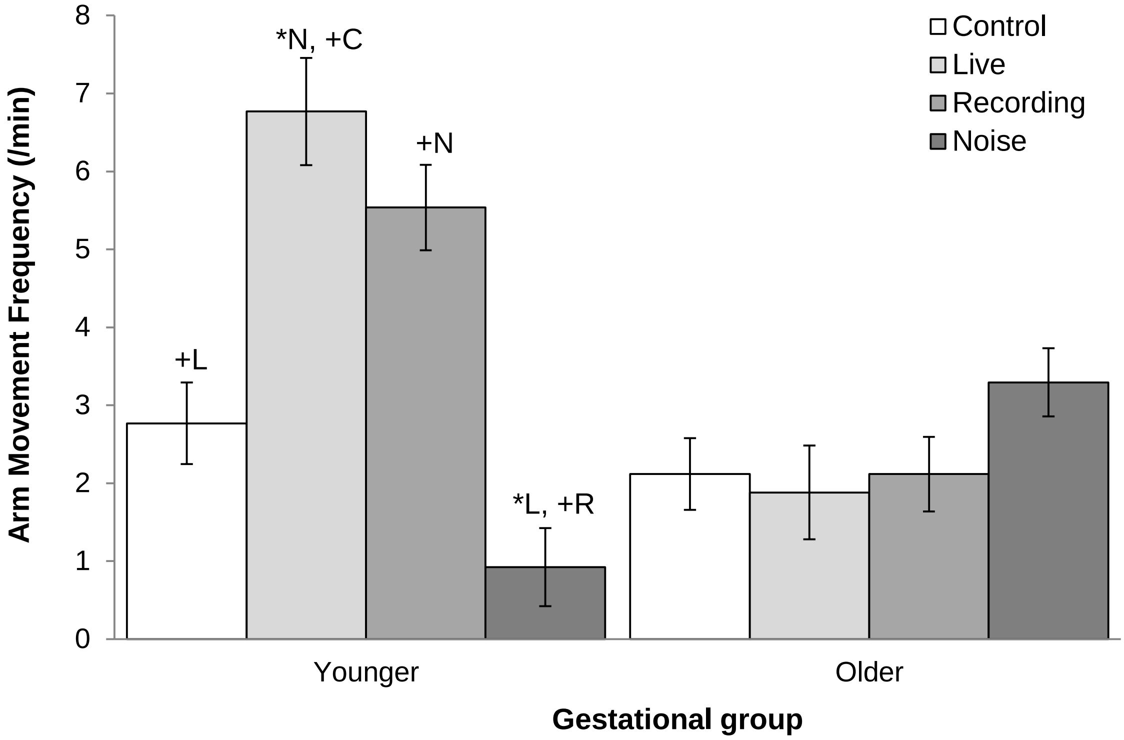

Figure 2.18. Average ‘Arm movement’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

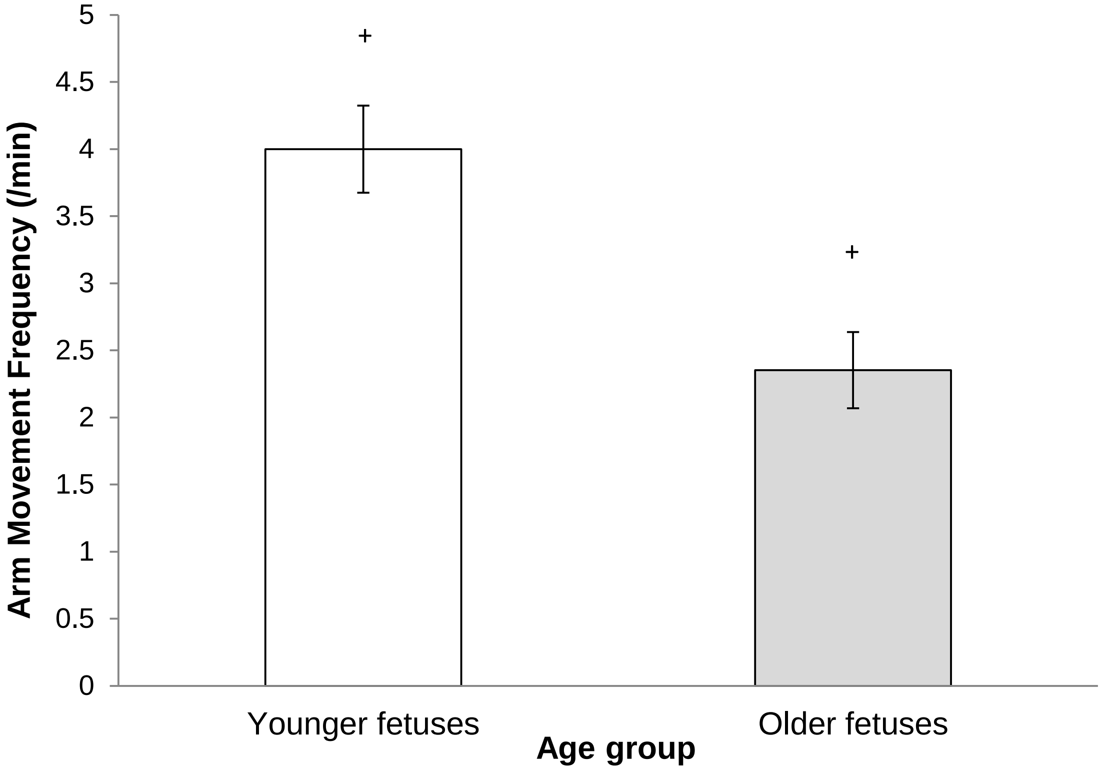

Figure 2.19. Average ‘Arm movement’ frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Arm Movement’ Duration*

A mixed ANOVA was conducted to assess differences in ‘Arm movement’ duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. Results indicated no significant main effects of Condition F (1.93, 53.91) = 1.21, p = .306, η_p^2 = .04, or GA F (1, 28) = 1.28, p = .267, η_p^2 = .04. However, a significant interaction between Condition and GA, F (1.93, 53.91) = 3.89, p = .028, η_p^2 = .12 was found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 28) = 7.42, p = .011, η_p^2 = .21.

Post-hoc analysis of the interaction showed that younger fetuses (M = 26.33) move significantly (p = .012) longer in ‘Live’ compared to older fetuses (M = 5.98). A tendency (p = .087) can be observed between age groups in ‘Recording’, with younger fetuses (M = 27.25) displaying less movements compared to older fetuses (M = 9.93). Younger fetuses displayed longer ‘Arm movement’ durations in ‘Live’ (M = 26.33) compared to ‘Control’ (M = 7.70, p =

.013). A tendency for longer 'Arm movement' duration was observed in 'Live' (M = 26.33) compared to 'Noise' (M = 7.03, *p* = .096) (see Figures 2.20 and 2.21). No further effects were found. The means and standard errors can be examined in Table 2.12.

Table 2.12. Means and standard errors (SE) of fetuses 'Arm movement' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	17.07	4.11	10.90	3.59		
Control	7.70	5.53	11.22	4.83	9.46	3.67
Live	26.33	5.67	5.98	4.96	16.15	3.77
Recording	27.25	7.36	9.93	6.44	18.59	4.89
Noise	7.03	6.87	16.46	6.00	11.74	4.56

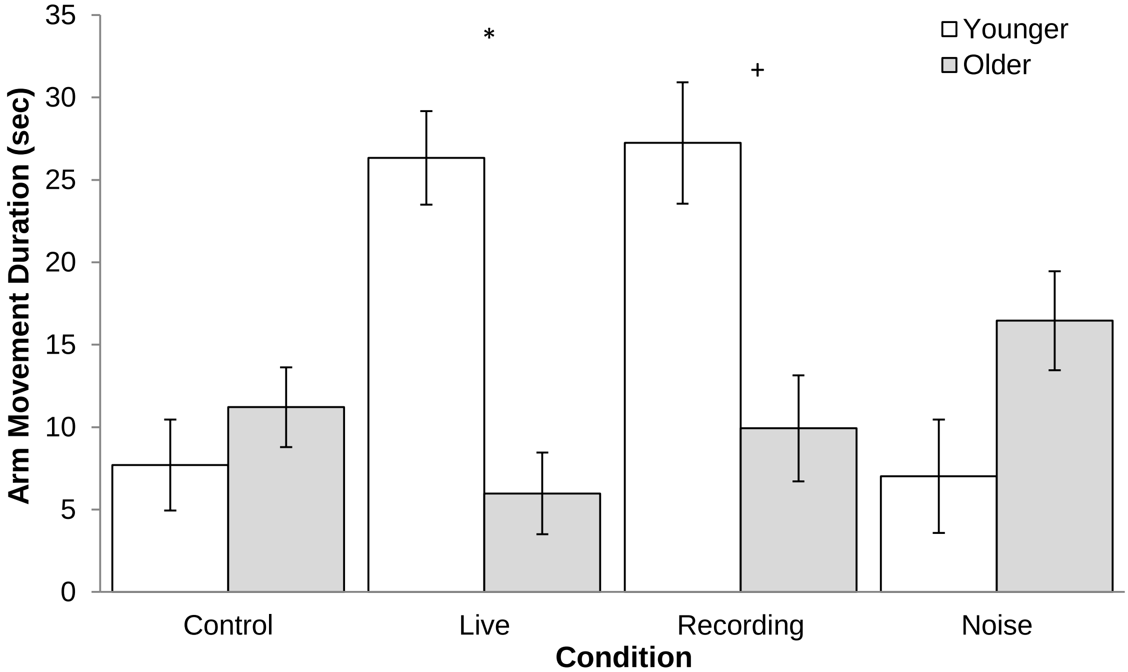

Figure 2.20. Average 'Arm movement' duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

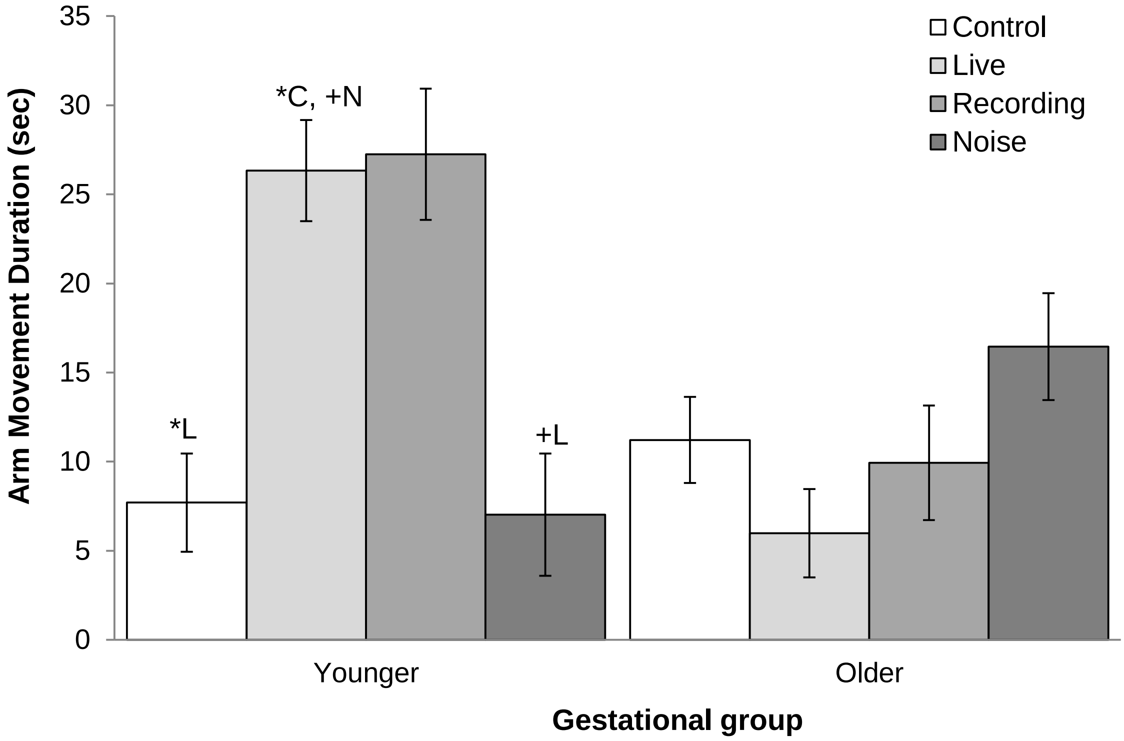

Figure 2.21. Average ‘Arm movement’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

*Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Frequency*

A mixed ANOVA was conducted to assess differences in ‘Uterus touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a significant interaction between Condition and GA, F (3, 84) = 5.04, p = .003, η_p^2 = .15. No main effects of Condition F (3, 84) = 2.04, p = .114, η_p^2 = .07, or GA F (1, 28) = 2.20, p = .149, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 8.98, p = .006, η_p^2 = .24 of Condition and GA. This finding is qualified by the significant quadratic trend of Condition and GA F (1, 28) = 5.47, p = .027, η_p^2 = .16.

Post-hoc analysis of the interaction showed that younger fetuses (M = 2.46) touch the uterus significantly more in ‘Live’ compared to older fetuses (M = 0.24, p = .012). A tendency was observed between age groups in ‘Noise’, with younger fetuses (M = 0.00) displaying a decrease in touch compared to older fetuses (M = 1.18, *p* = .083). Younger fetuses increased ‘Uterus touch’ frequency significantly in ‘Live’ (M = 2.46) compared to ‘Noise’ (M = 0.00, *p* = .013) (see Figures 2.22 and 2.23). No further effects were found. The means and standard errors can be examined in Table 2.13.

Table 2.13. Means and standard errors (SE) of fetuses ‘Uterus touch’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.23	0.27	0.71	0.23		
Control	0.92	0.38	0.24	0.33	0.58	0.25
Live	2.46	0.51	0.24	0.45	1.35	0.34
Recording	1.54	0.54	1.18	0.47	1.36	0.36
Noise	0.00	0.49	1.18	0.43	0.59	0.33

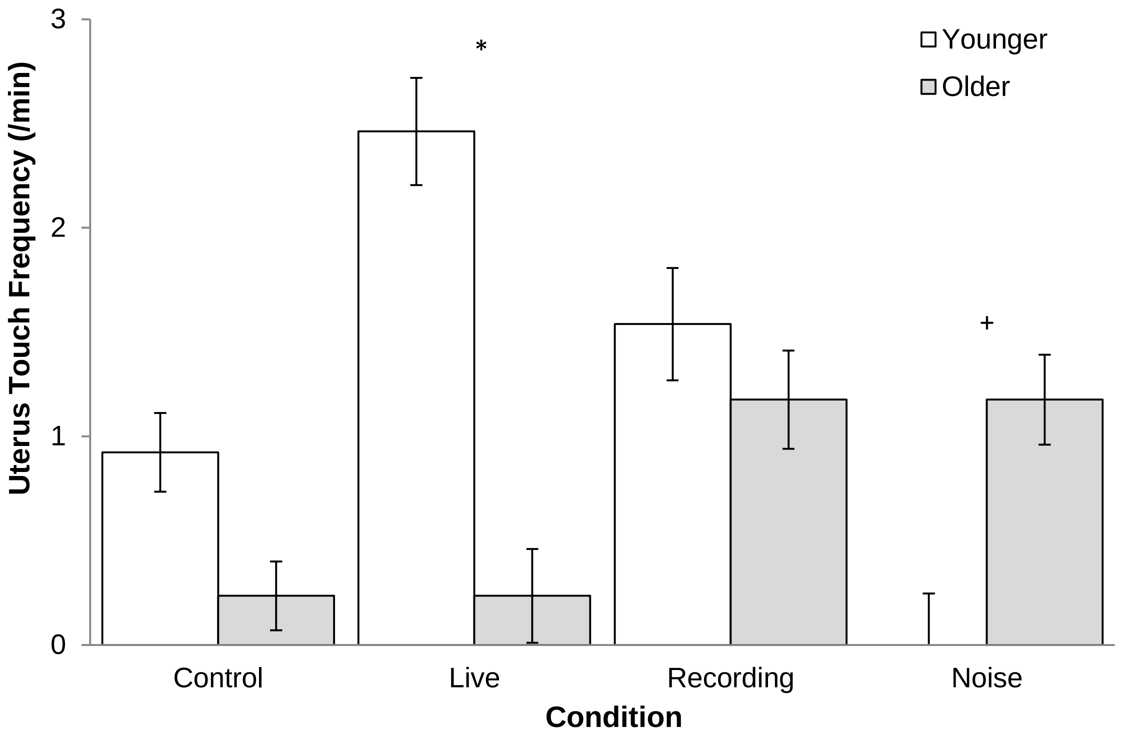

Figure 2.22. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

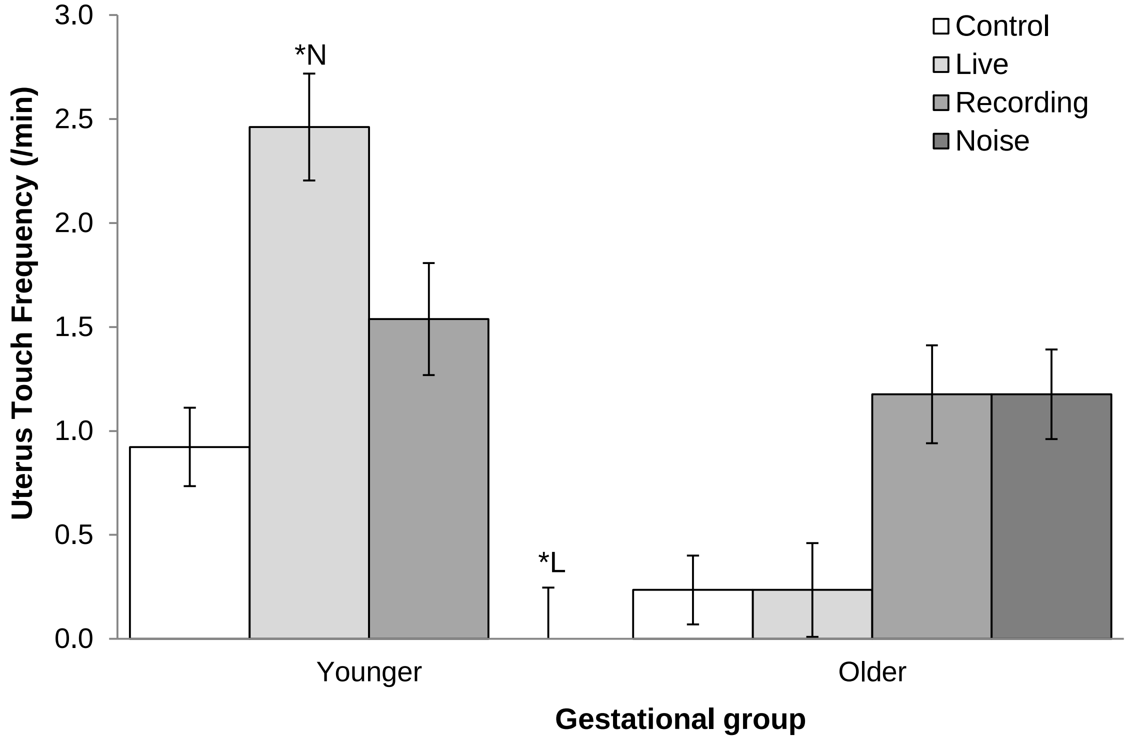

Figure 2.23. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Duration*

A mixed ANOVA was conducted to assess differences in ‘Uterus touch’ duration and GA across the four Conditions (Control, Live, Recording, Noise). A significant interaction between Condition and GA, F (3, 84) = 3.11, p = .031, η_p^2 = .10 was found. No main effects of Condition F (3, 84) = 1.70, p = .174, η_p^2 = .06, or GA F (1, 28) = 1.37, p = .251, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a linear trend F (1, 28) = 7.25, p = .012, η_p^2 = .21 of Condition and GA.

Post-hoc analysis of the interaction showed that younger fetuses (M = 37.32) touch the uterus significantly longer in ‘Live’ compared to older fetuses (M = 5.88, p = .022). A further tendency was observed between age groups in ‘Noise’, with younger fetuses (M = 0.00) touching less compared to older fetuses (M = 7.25, p = .083). Younger fetuses displayed a tendency towards increased ‘Uterus touch’ duration in ‘Live’ (M = 37.32, p = .052) and ‘Recording’ (M = 32.93, p = .074) compared to ‘Noise’ (M = 0.00) (see Figures 2.24 and

2.25). No further effects were found. The means and standard errors can be examined in Table 2.14.

Table 2.14. Means and standard errors (SE) of fetuses ‘Uterus touch’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	23.32	6.00	13.98	5.25		
Control	23.01	9.43	5.88	8.25	14.45	6.26
Live	37.32	9.74	5.88	8.52	21.60	6.47
Recording	32.93	12.30	23.90	10.75	28.42	8.17
Noise	0.00	8.29	20.27	7.25	10.14	5.51

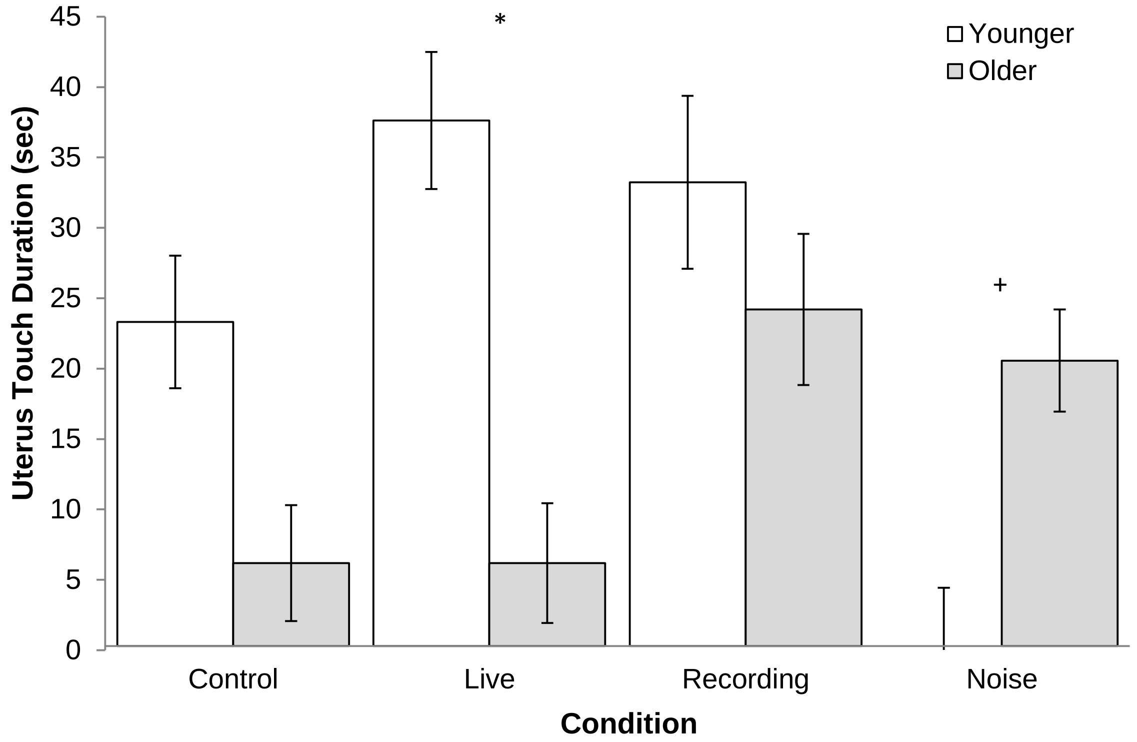

Figure 2.24. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

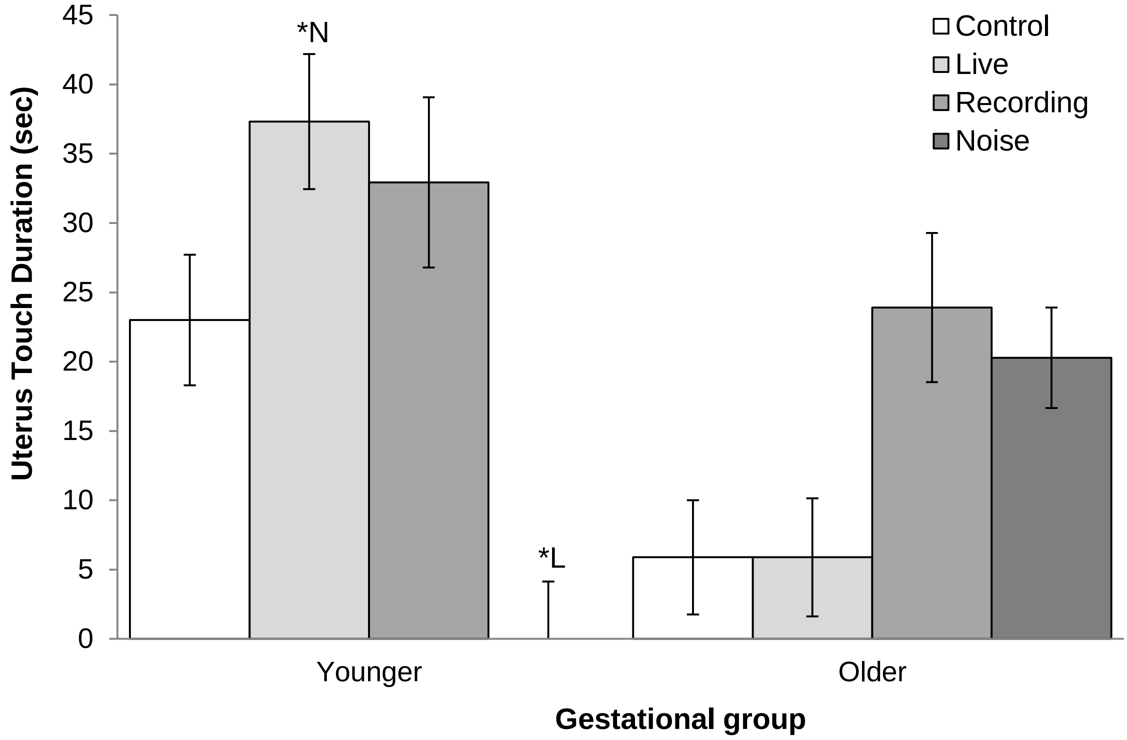

Figure 2.25. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Face press’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. The Condition main effect indicates a trend, F (2.59, 72.41) = 2.76, p = .056, η_p^2 = .09. Neither main effects of GA F (1, 28) = 0.09, p = .767, η_p^2 < .001, nor an interaction F (3, 84) = 1.40, p = .249, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 28) = 7.53, p = .011, η_p^2 = .21 of Condition, indicating a decrease from ‘Control’ (M = 0.85) over ‘Live’ (M = 0.92) to ‘Recording’ (M = 0.63) followed by an increase to ‘Noise’ (M = 1.85).

Post-hoc analysis of the main effect of Condition showed a tendency between ‘Control’ and ‘Noise’ with a higher frequency in ‘Face press’ in ‘Noise’ (M = 1.86) compared to ‘Control’ (M = 0.85, p = .080) with no other significant differences between conditions (see Figure 2.26). No further effects were found. The means and standard errors can be examined in Table 2.15.

Table 2.15. Means and standard errors (SE) of fetuses 'Face press' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.15	0.35	1.29	0.31		
Control	1.23	0.45	0.47	0.39	0.85	0.30
Live	0.92	0.53	1.65	0.47	1.29	0.35
Recording	0.62	0.48	1.18	0.42	0.90	0.32
Noise	1.85	0.57	1.88	0.50	1.86	0.38

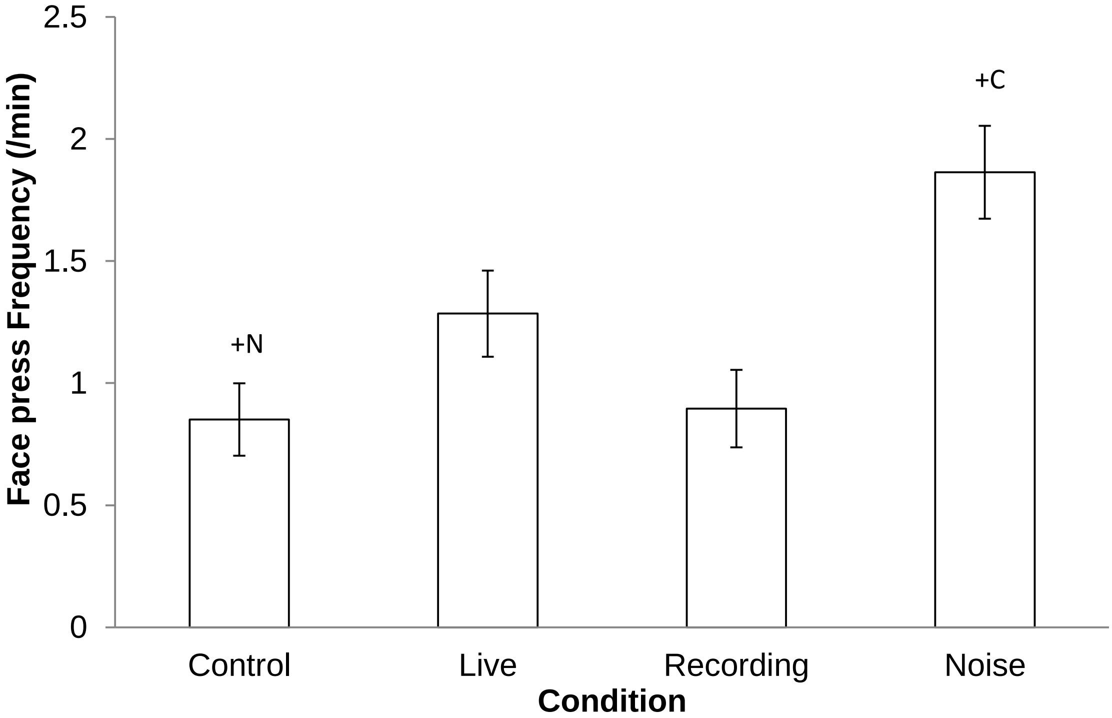

Figure 2.26. Average 'Face press' frequency (per minute) including standard errors for each Condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Face press' Duration*

A mixed design ANOVA was conducted to assess differences in 'Face press' duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. The Condition main effect indicates a trend, F (2.24, 62.66) = 2.94, p = .055, η_p^2 = .10. No main effects of GA F (1, 28) = 0.17, p = .679, η_p^2 = .01, nor an interaction F (2.24, 62.66) = 1.84, p = .163, η_p^2 = .06, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 4.46, p = .044, η_p^2 = .14, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 28) = 6.83, p = .014, η_p^2 = .20. Overall, there is a linear increase produced by the means from 'Control' (M = 21.27) to the 'Noise' condition (M = 46.61). However, the 'Recording' condition has a somewhat lower mean (M = 22.40) than the 'Live' condition (M = 29.29) producing the cubic trend.

Post-hoc analysis of the main effect of Condition showed a tendency between 'Control' and 'Noise' with a longer duration of 'Face press' in 'Noise' (M = 46.61) compared to 'Control' (M = 21.27, p = .080) (see Figure 2.27). No further effects were found. The means and standard errors can be examined in Table 2.16.

Table 2.16. Means and standard errors (SE) of fetuses 'Face press' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	27.43	8.88	32.35	7.77		
Control	30.77	11.16	11.77	9.76	21.28	7.41
Live	17.40	12.62	41.18	11.03	29.29	8.38
Recording	15.39	11.98	29.41	10.47	22.40	7.96
Noise	46.15	14.32	47.06	12.52	46.61	9.51

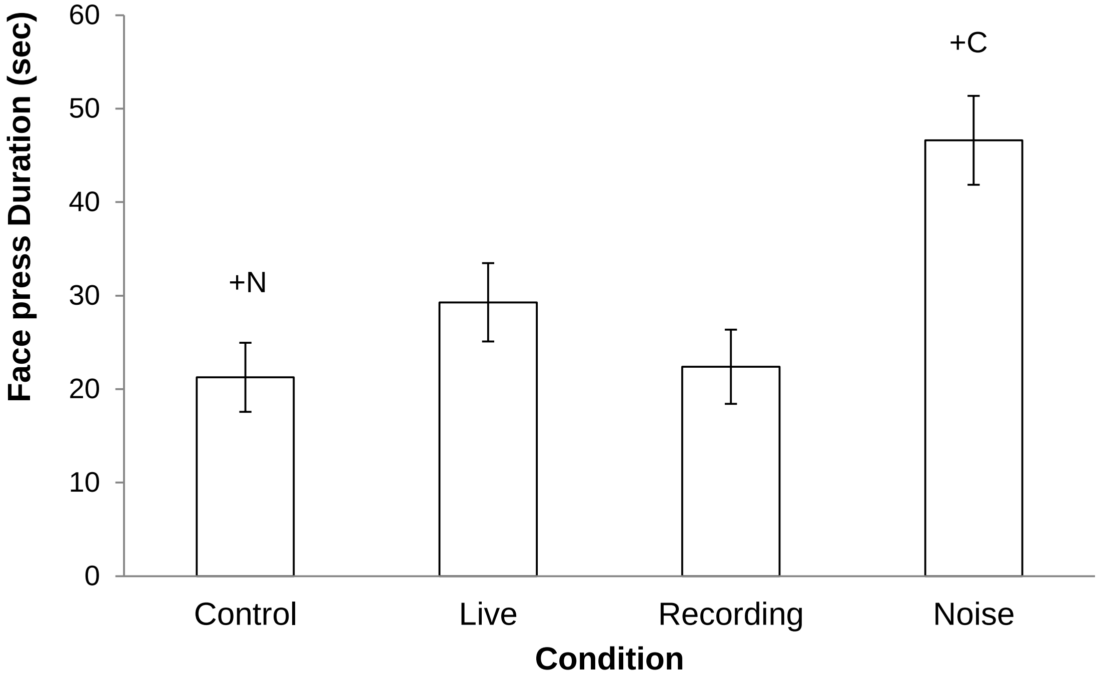

Figure 2.27. Average ‘Face press’ duration (per minute) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Head Movement’ Duration*

A mixed ANOVA was conducted to assess differences in frequency of ‘Head movements’ and GA across the four Conditions (Control, Live, Recording, Noise). The Condition main effect indicates a tendency, F (3, 84) = 2.24, p = .090, η_p^2 = .07, suggesting that head movement frequency tends to differ between Conditions. No main effect of GA F (1, 28) = 1.77, p = .195, η_p^2 = .06, or an interaction F (3, 84) = 1.05, p = .163, η_p^2 = .04, were found. In support of this polynomial contrasts indicated a quadratic trend F (1, 28) = 3.44, p = .074, η_p^2 = .11, of Condition, showing that frequency increases from ‘Control’ (M = 1.91) over ‘Live’ (M = 9.01) to ‘Recording’ (M = 9.63), followed by a decrease in the ‘Noise’ condition (M = 5.76).

Post-hoc analysis revealed no significant differences or tendencies between conditions (see Figure 2.28). No further effects were found. The means and standard errors can be examined in Table 2.17.

Table 2.17. Means and standard errors (SE) of fetuses head movement duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	8.54	2.22	4.61	1.94		
Control	2.88	1.26	0.93	1.10	1.91	0.84
Live	12.59	4.32	5.43	3.78	9.01	2.87
Recording	13.90	4.97	5.35	4.34	9.63	3.30
Noise	4.78	3.60	6.74	3.15	5.76	2.39

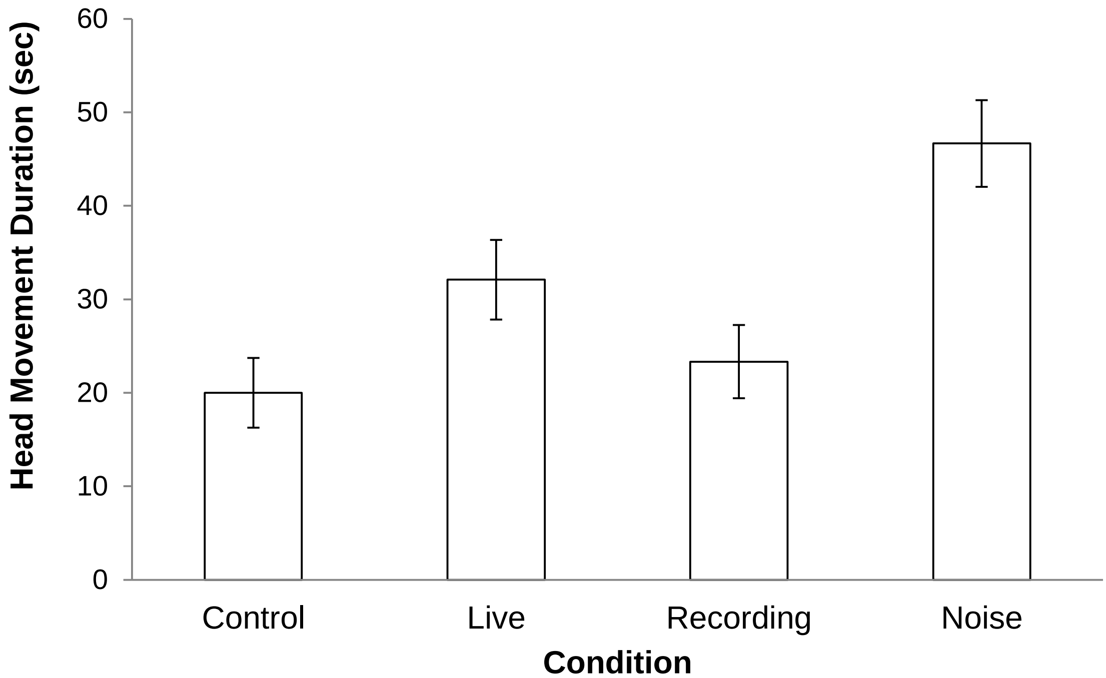

Figure 2.28. Average head movement duration in seconds including standard errors for each condition.

0-15 Interval analysis combined

*Mixed-design ANOVA Condition*GA: 'General Movement' Frequency*

A mixed design ANOVA was conducted to assess differences in 'General movement' frequency and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed a marginally significant main effect of Condition F (3, 84) = 2.35, p = .078, η_p^2 = .08, and GA F (1, 28) = 4.11, p = .052, η_p^2 = .13. Furthermore, a significant interaction between Condition and GA, F (3, 84) = 4.50, p = .006, η_p^2 = .14, was found. Polynominal contrasts indicated a significant quadratic trend of Condition and GA F (1, 28) = 10.86, p = .003, η_p^2 = .28. In support of this polynomial contrasts indicated a significant quadratic trend of Condition F (1, 28) = 7.61, p = .010, η_p^2 = .21, reflecting an increase from 'Control' (M = 3.87) to 'Live' (M = 6.50) and 'Recording' (M = 7.27), followed by a decrease to 'Noise' (M = 3.86).

Post-hoc analysis of the main effect of 'Condition' revealed no further effects (see Figure 2.29).

Post-hoc analysis of the interaction showed a significant difference in 'Recording' between younger and older fetuses, with younger fetuses (M = 10.77) displaying more 'General Movements' compared to older fetuses (M = 3.76, p = 0.21). A significant difference was found in 'Live' with younger fetuses (M = 9.23) moving more frequently compared to older fetuses (M = 3.76, p = .045). A marginally significant difference was found in 'Noise' with older fetuses (M = 5.88) moving more frequently compared to younger fetuses (M = 1.85, p = .057). Further significant differences were observed amongst younger fetuses between 'Noise' and 'Recording', with increased 'General movement' frequency in 'Recording' (M = 10.77) compared to 'Noise' (M = 1.85, p = .006). Marginally significant differences can be observed in younger fetuses between 'Live' and 'Noise', with increased movement frequency in 'Live' (M = 9.23) compare to 'Noise' (M = 1.85, p = .069), and between 'Control' and 'Recording', with increased 'General movement' frequencies during 'Recording' (M = 10.77) compared to 'Control' (M = 4.92, p = .073) (see Figures 2.30 and 2.31).

Marginally significant differences were found for the main effect of GA, with younger fetuses (M = 6.69) displaying more 'General movements' compared to older fetuses (M = 4.06, p = .052) (see Figure 2.32). No further effects were found. The means and standard errors can be examined in Table 2.18.

Table 2.18. Means and standard errors (SE) of fetuses ‘General movement’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	6.69	0.98	4.06	0.86		
Control	4.92	1.42	2.82	1.24	3.87	0.94
Live	9.23	1.96	3.77	1.72	6.50	1.30
Recording	10.77	2.16	3.77	1.89	7.27	1.43
Noise	1.85	1.53	5.88	1.34	3.86	1.02

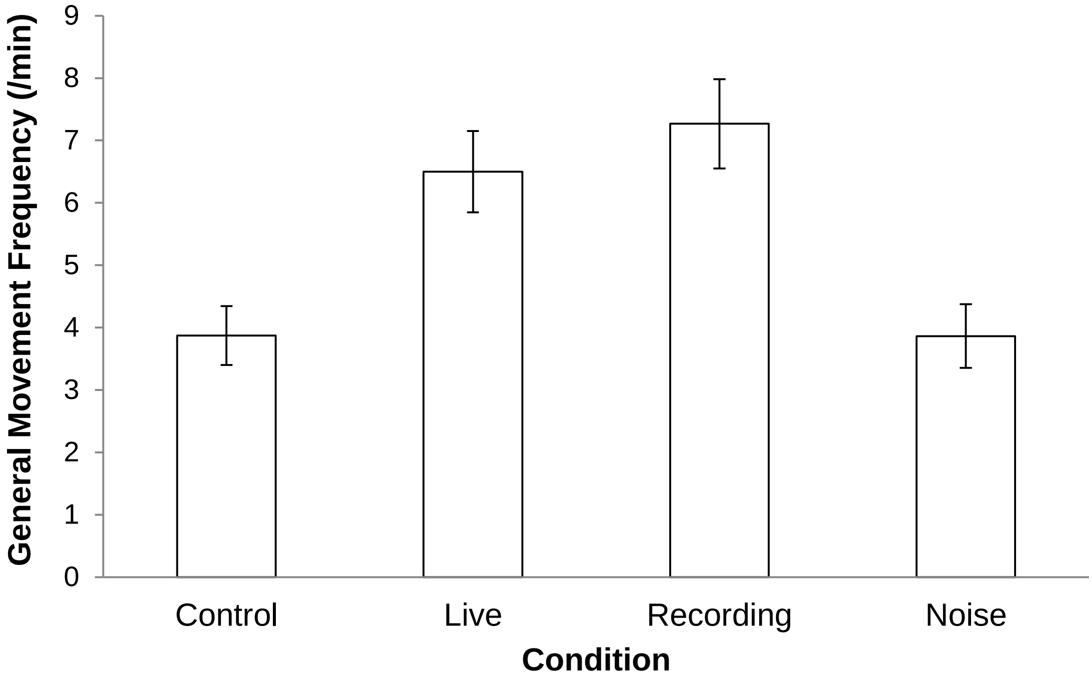

Figure 2.29. Average ‘General movement’ frequency (per minute) including standard errors for each condition.

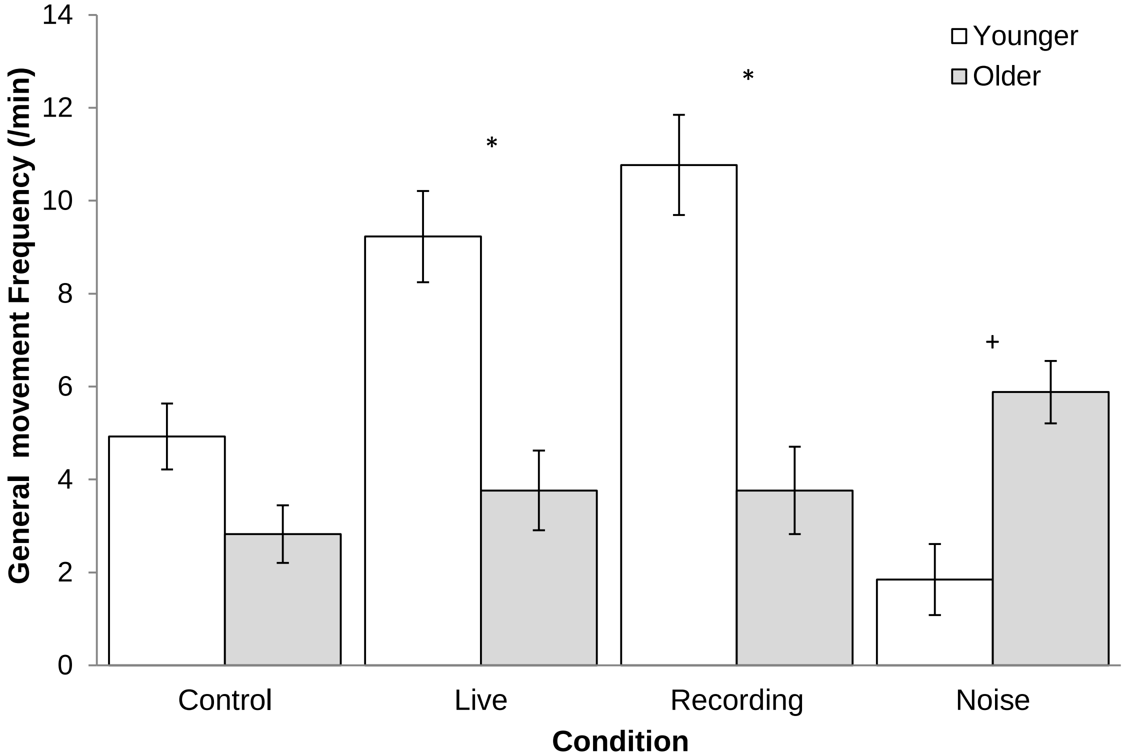

Figure 2.30. Average ‘General movement’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, * < .05).

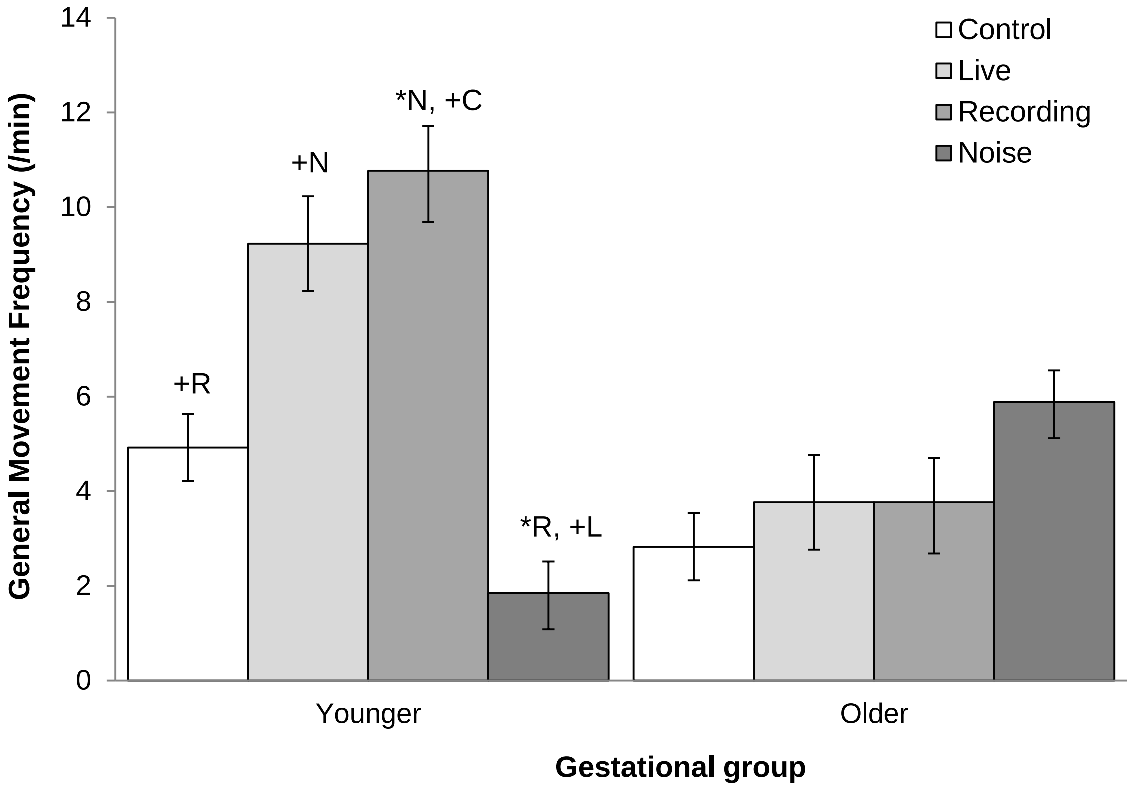

Figure 2.31. Average ‘General movement’ frequency (per minute) including

standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

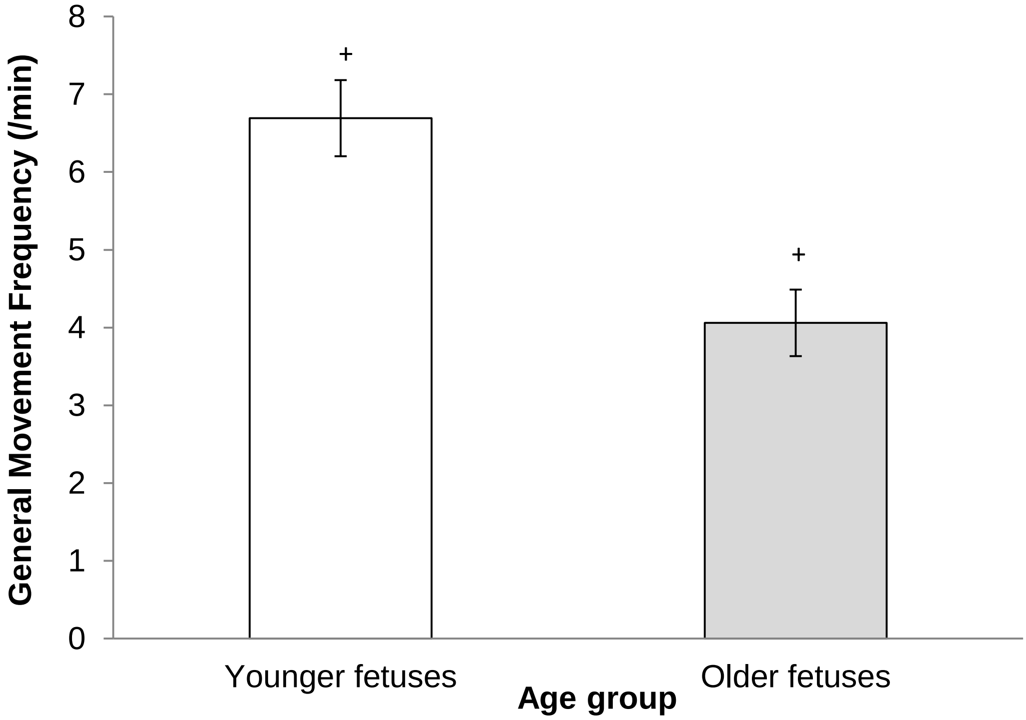

Figure 2.32. Average ‘General Movement’ frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘General Movement’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘General movement’ duration and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effects of Condition F (3, 84) = 1.98, p = .123, η_p^2 = .07, and GA F (1, 28) = 1.81, p = .190, η_p^2 = .06. However, a significant interaction between Condition and GA, F (3, 84) = 3.28, p = .025, η_p^2 = .11, was found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 28) = 6.14, p = .020, η_p^2 = .18. Post-hoc analysis of the interaction showed a significant difference in ‘Recording’ between younger and older fetuses, with younger fetuses (M = 4.11) displaying longer ‘General movements’ compared to older fetuses (M = 1.53, p = .032). Further significant differences were revealed for younger fetuses in between ‘Control’ and ‘Live’, with longer movements in ‘Live’ (M = 1.06) compared to ‘Control’ (M = 1.06, p = .011) (see Figures 2.33 and 2.34).

No further effects were found. The means and standard errors can be examined in Table 2.19.

Table 2.19. Means and standard errors (SE) of fetuses ‘General movement’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.56	0.57	1.55	0.50		
Control	1.06	0.60	1.22	0.52	1.14	0.40
Live	3.89	0.92	1.14	0.80	2.52	0.61
Recording	4.11	1.17	1.53	1.03	2.82	0.78
Noise	1.18	0.83	2.32	0.72	1.75	0.55

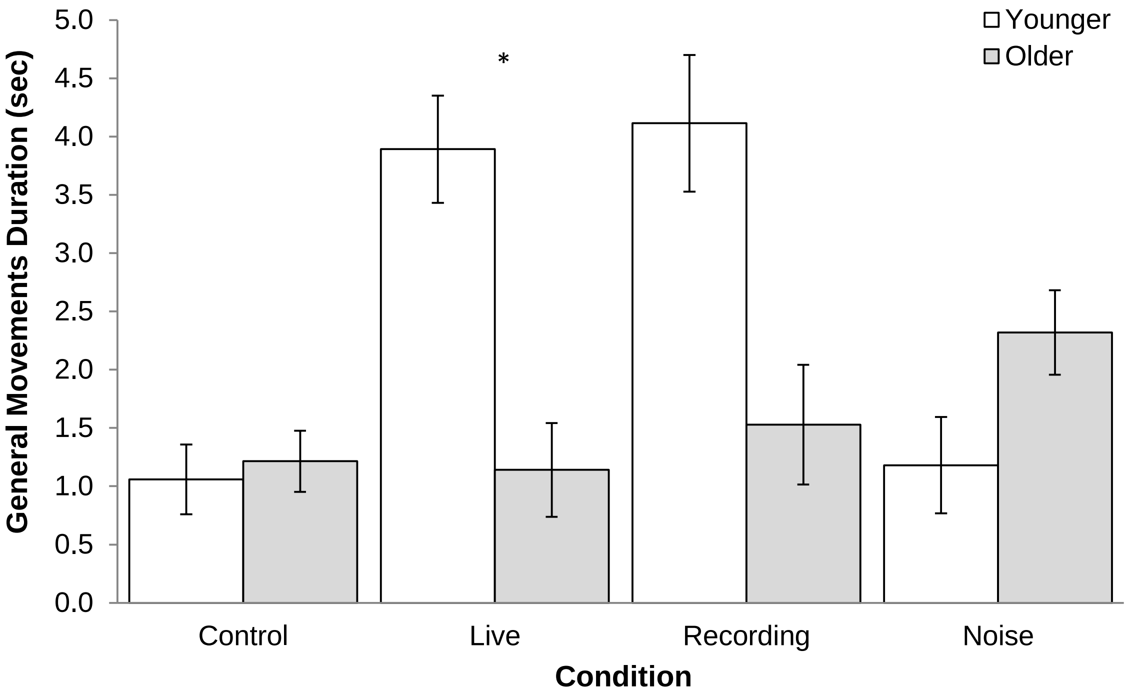

Figure 2.33. Average ‘General movement’ duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, * < .05).

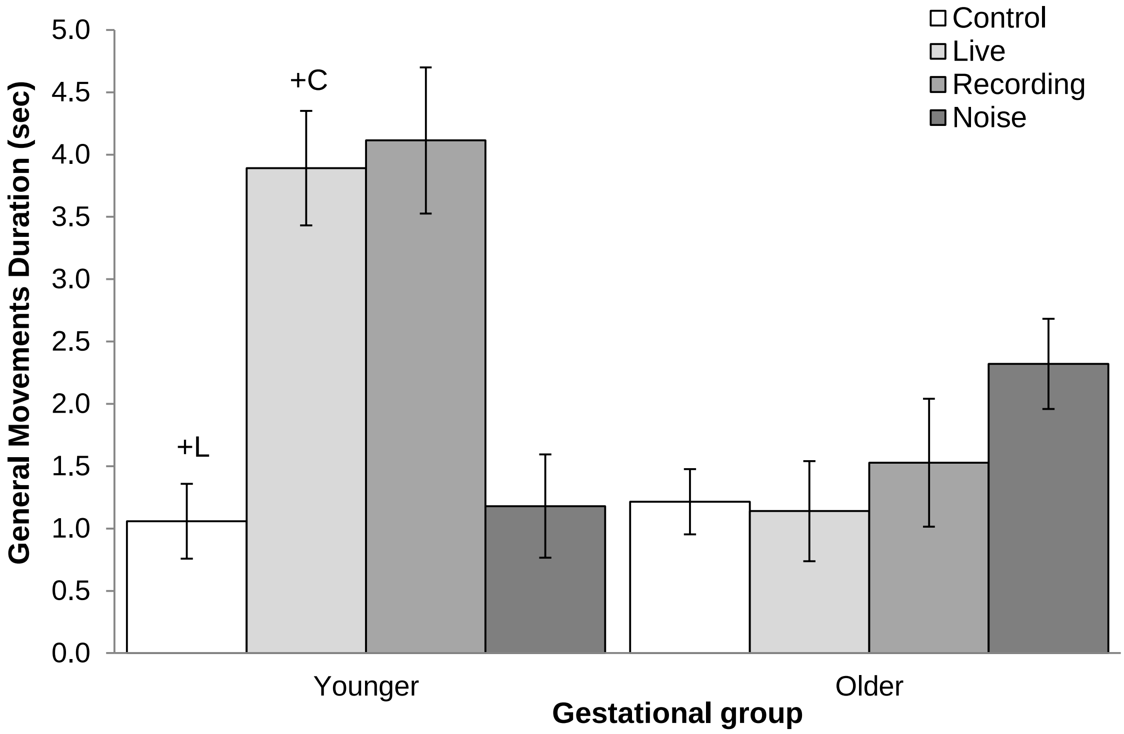

Figure 2.34. Average 'General movement' duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'External Touch' Frequency*

A mixed design ANOVA was conducted to assess differences in 'External touch' duration and GA across the four Conditions (Control, Live, Recording, Noise). Results showed no significant main effects of Condition F (3, 84) = 1.41, p = .246, η_p^2 = .05, and GA F (1, 28) = 0.31, p = .580, η_p^2 = .01. However, a marginally significant interaction between Condition and GA, F (3, 84) = 2.19, p = .095, η_p^2 = .07, was found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 28) = 6.14, p = .020, η_p^2 = .18.

Post-hoc analysis of the interaction showed a significant difference for older fetuses between 'Control' and 'Noise', with more 'External touch' in 'Noise' (M = 3.06) compared to 'Control' (M = 0.71, p = .015) (see Figures 2.35 and 2.36). No further effects were found. The means and standard errors can be examined in Table 2.20.

Table 2.20. Means and standard errors (SE) of fetuses ‘External touch’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.39	0.52	2.00	0.45		
Control	2.15	0.72	0.71	0.63	1.43	0.48
Live	3.39	0.84	1.88	0.73	2.63	0.56
Recording	2.15	0.82	2.35	0.72	2.25	0.55
Noise	1.85	0.74	3.06	0.64	2.45	0.49

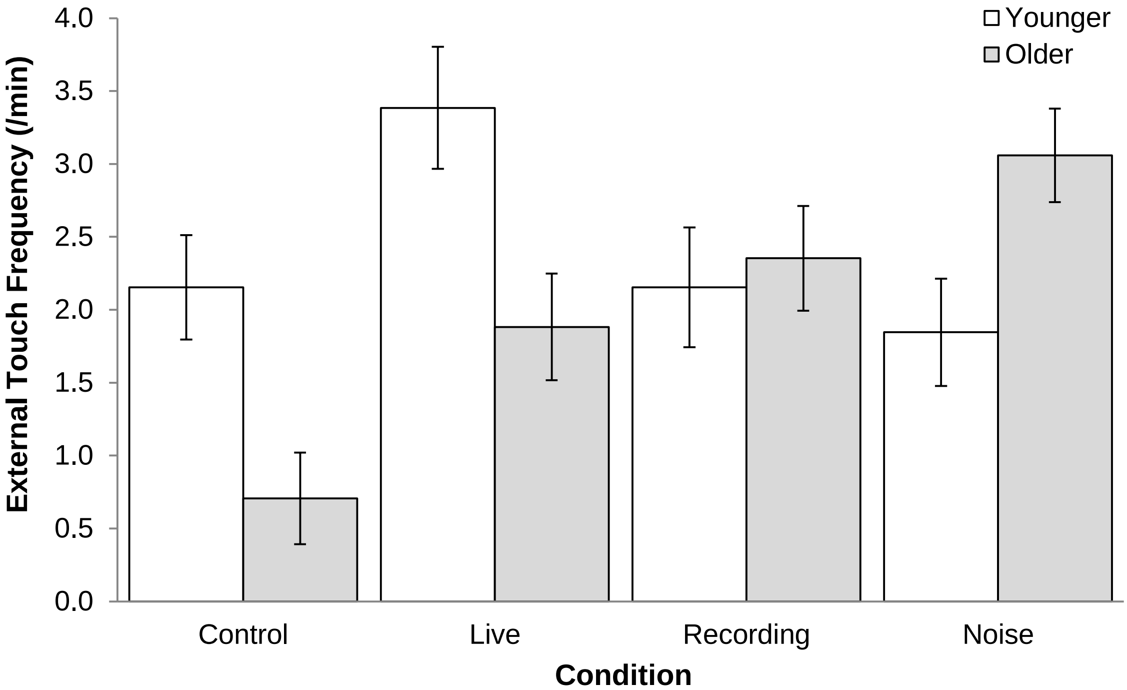

Figure 2.35. Average ‘‘External touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses).

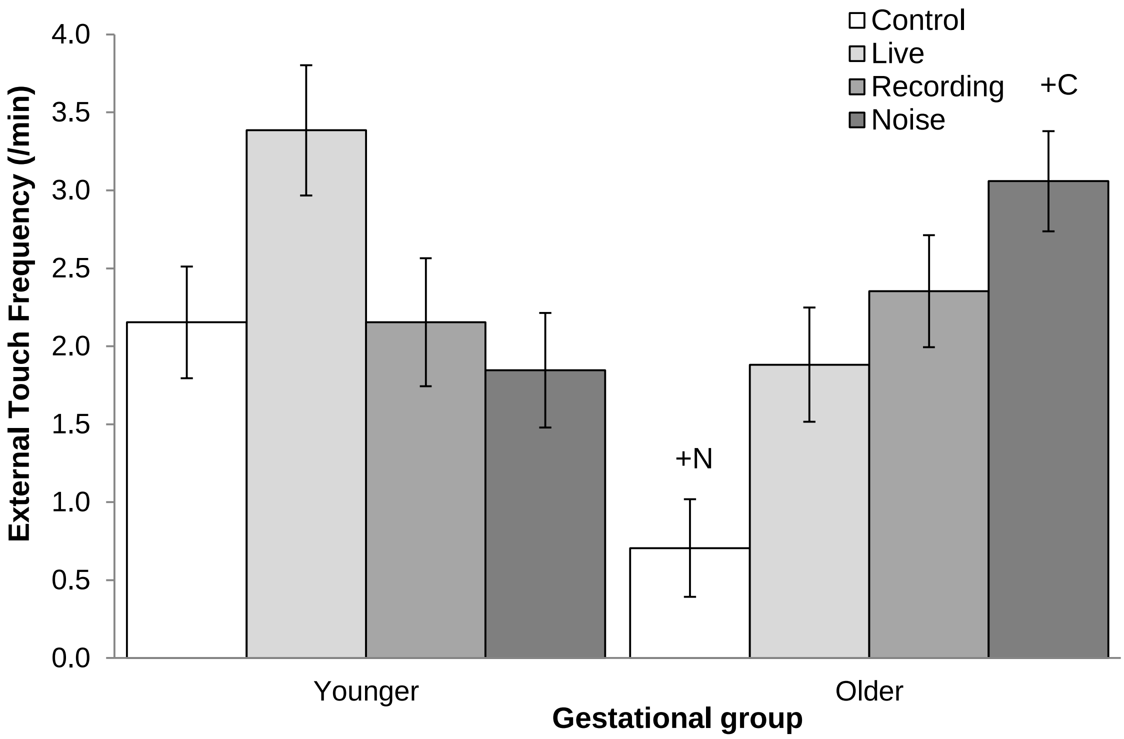

Figure 2.36. Average ‘External touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

0-30 Interval analysis

Repeated-measures ANOVA Condition: ‘Face press’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). As the assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results indicate that there was a trend in ‘Face press’ frequency between the four Conditions F (2.53, 73.40) = 2.89, p = .055, $\eta_p^2 = .09$.

Examination of these means suggests that fetuses ‘Face press’ frequency changed depending on Condition. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 4.62, p = .040, $\eta_p^2 = .14$. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.37, p = .007, $\eta_p^2 = .22$. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.40) to the ‘Noise’ condition (M = 0.93). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.47) than the ‘Live’ condition (M = 0.67) producing the cubic trend.

Post-hoc analysis showed a trend between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ frequency in ‘Noise’ (M = 0.93) compared to ‘Control’ (M = 0.40, *p* = .053) (see Figure 2.37). No further effects were found. The means and standard errors can be examined in Table 2.21.

Table 2.21. Means and standard errors (SE) on the frequency of fetuses facial touch of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	0.40	0.67	0.47	0.93
SE	0.15	0.18	0.16	0.19

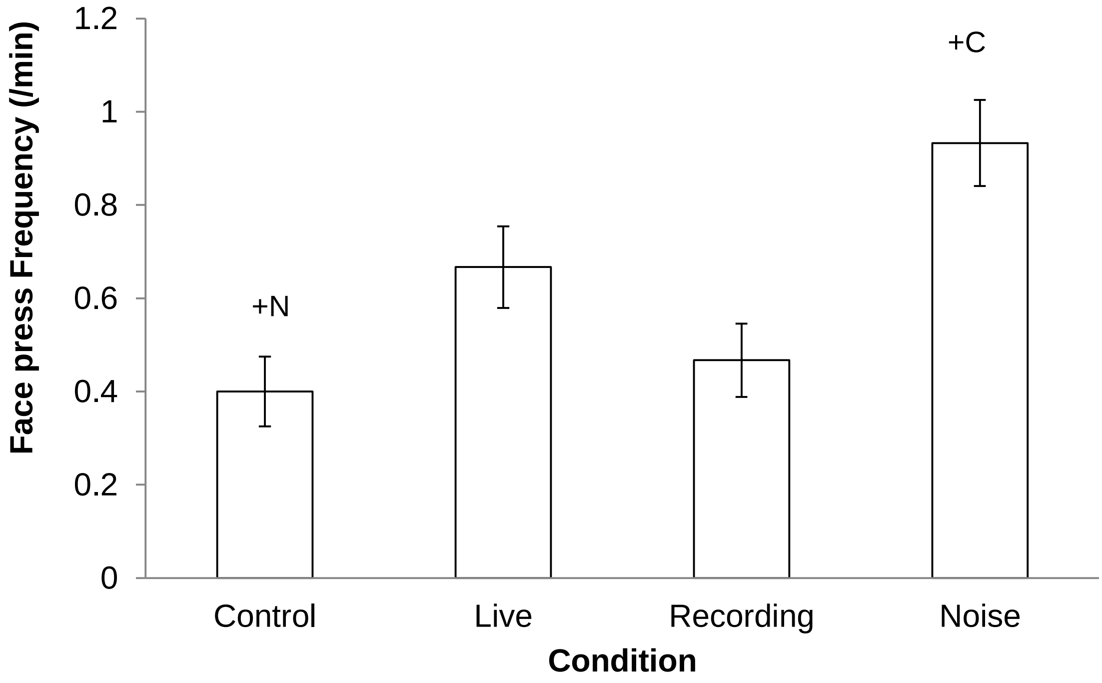

Figure 2.37. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: 'Face press' Duration

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in duration of the 'Face press' between the four Conditions (Control, Live, Recording, Noise). Examination of these means suggests that 'Face press' duration differentiated between Conditions. Results indicate that there was a significant difference in 'Face press' duration between the four Conditions F (2.5, 72.39) = 2.96, p = .047, η_p^2 = .09. Examination of these means suggests that the duration of 'Face press' differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 4.84, p = .036, η_p^2 = .14. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.37, p = .007, η_p^2 = .22. Overall, the linear increase is produced by the means from 'Control' (M = 20.00) to the 'Noise' condition (M = 46.67). However, the 'Recording' condition has a somewhat lower mean (M = 23.33) than the 'Live' condition (M = 32.10) producing the cubic trend.

Post-hoc analysis showed a trend between 'Noise' and 'Control', with fetuses increasing 'Face press' duration in the 'Noise' (M = 46.67) condition compared to 'Control' (M = 20.00, p = .053) (see Figure 2.38). No further effects were found. The means and standard errors can be examined in Table 2.22.

Table 2.22. Means and standard errors (SE) on the duration of fetuses facial touch of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	20.00	32.10	23.33	46.67
SE	7.43	8.51	7.85	9.26

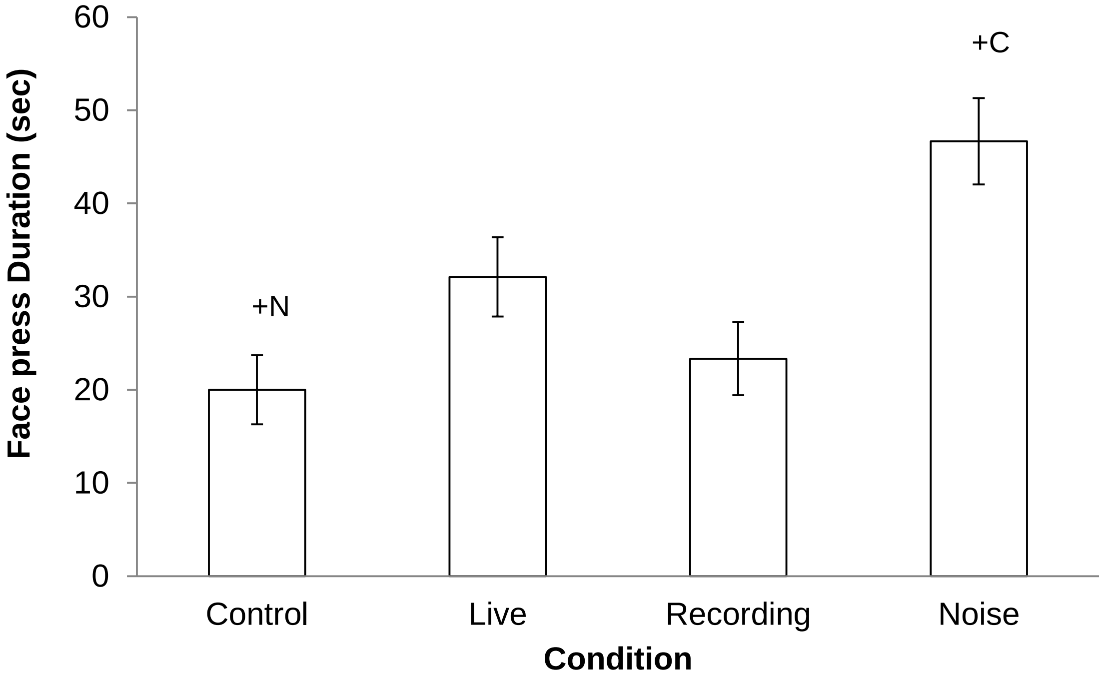

Figure 2.38. Average 'Face press' duration (per minute) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Arm Movement' Frequency*

A mixed design ANOVA was conducted to assess differences in 'Arm movement' frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results showed a significant interaction between Condition and GA, F (3, 84) = 4.45, p = .006, η_p^2 = .14, showing that 'Arm movement' frequency is dependent on Condition and GA. A tendency for GA F (1, 28) = 3.21, p = .084, η_p^2 = .10, was found showing that 'Arm movement' frequency is dependent on GA. No main effect of Condition was found F (3, 84) = 1.33, p = .272, η_p^2 = .05. In support of this polynomial contrasts indicated a significant linear trend of Condition and GA F (1, 28) = 5.53, p = .026, η_p^2 = .17. However, this finding was qualified by the significant quadratic trend of Condition and GA F (1, 28) = 9.45, p = .005, η_p^2 = .25.

Post-hoc pairwise comparison of the main effect of GA showed that younger fetuses (M = 3.62) tend to display more 'Arm movement's (p = .084) compared to older fetuses (M = 2.41) (see Figure 2.41).

Post-hoc analysis of the interaction showed that in the ‘Live’ condition younger fetuses (M = 5.39) increased ‘Arm movement’s significantly compared to older fetuses (M = 2.00, *p* = .022). The same significant difference can be observed in the ‘Recording’ condition (younger fetuses: M = 4.92; older fetuses: 2.12; *p* = .035), whereas in the ‘Noise’ condition older fetuses (M = 3.41) significantly increased ‘Arm movement’ frequency compared to younger fetuses (M = 1.08, *p* = .043). Younger fetuses displayed significantly more ‘Arm movements’ in ‘Live’ (M = 5.39) compared to ‘Noise’ (M = 1.08, *p* = .007) and displayed a tendency of more ‘Arm movements’ in ‘Recording’ (M = 4.92) over ‘Noise’ (M = 1.08, *p* = .072) (see Figures 2.39 and 2.40). No further effects were found. The means and standard errors can be examined in Table 2.23.

Table 2.23. Means and standard errors (SE) of fetuses ‘Arm movement’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.62	0.51	2.41	0.44		
Control	3.08	0.93	2.12	0.81	2.60	0.62
Live	5.39	1.05	2.00	0.92	3.69	0.70
Recording	4.92	0.95	2.12	0.83	3.52	0.63
Noise	1.08	0.83	3.41	0.73	2.24	0.55

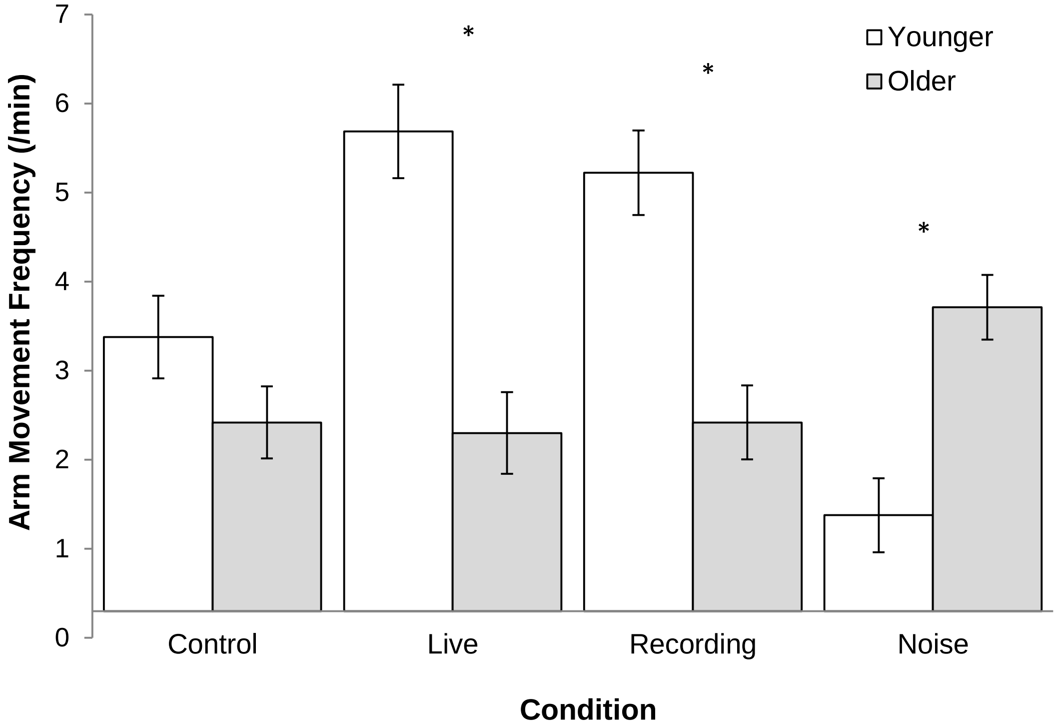

Figure 2.39. Average ‘Arm movement’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (*< .05).

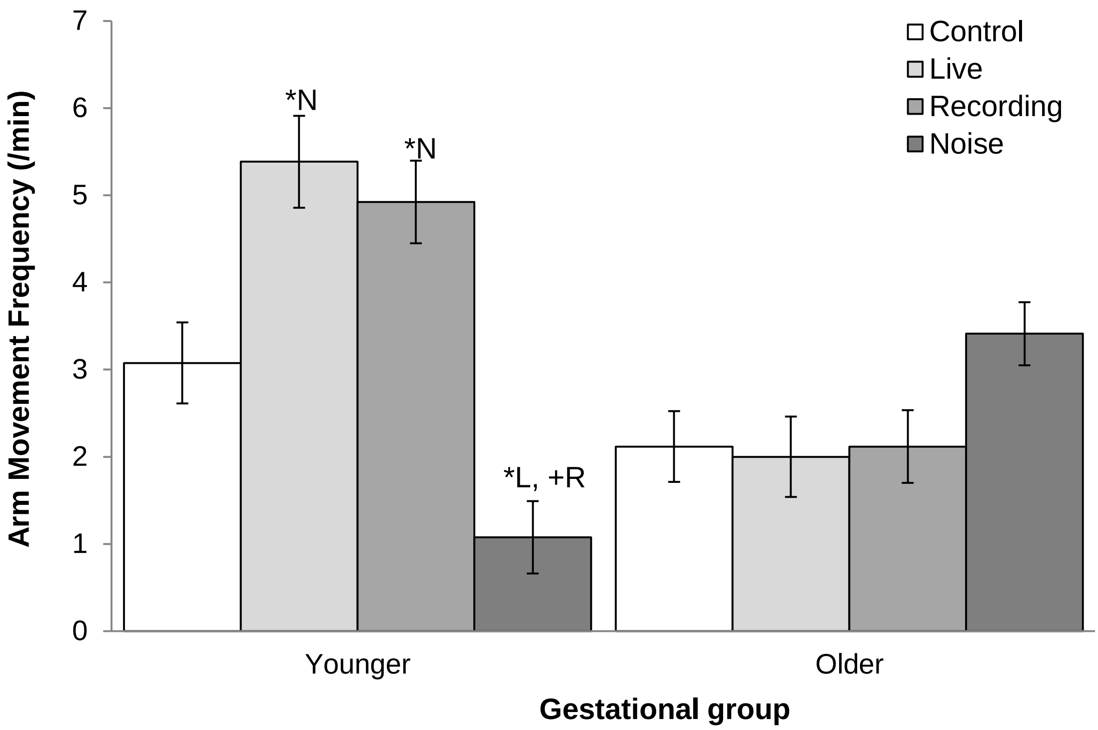

Figure 2.40. Average ‘Arm movement’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

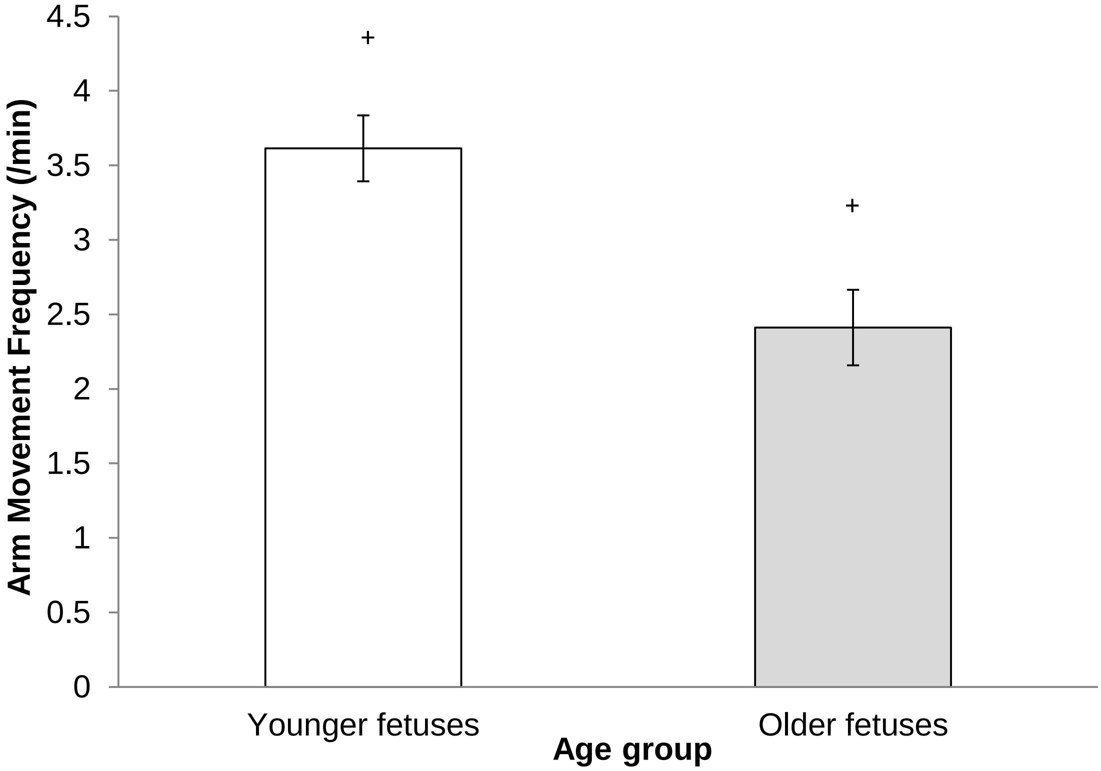

Figure 2.41. Average ‘Arm movement’ frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Arm Movement’ Duration*

A mixed ANOVA was conducted to assess differences in ‘Arm movement’ duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. Results indicated a significant interaction between Condition and GA, F (2.20, 61.52) = 4.51, p = .012, η_p^2 = .14. No main effects of Condition F (2.20, 61.52) = 1.28, p = .286, η_p^2 = .04, or GA F (1, 28) = 0.62, p = .438, η_p^2 = .02, were found. In support of this polynomial contrasts indicated a quadratic trend of Condition and GA F (1, 28) = 7.94, p = .009, η_p^2 = .22.

Post-hoc analysis of the interaction showed that younger fetuses (M = 27.93) move significantly longer in ‘Live’ compared to older fetuses (M = 7.70, p = .011). A tendency can be observed in the ‘Recording’ condition, with younger fetuses (M = 27.93) moving arms longer compared to older fetuses (M = 12.56, p = .096). Younger fetuses moved their arms significantly longer in ‘Live’ (M =

24.73) compared to 'Noise' (M = 4.65, *p* = .010) and displayed the same tendency for 'Recording' (M = 27.93) compared to 'Noise' (M = 4.65, *p* = .087) (see Figures 2.42 and 2.43). No further effects were found. The means and standard errors can be examined in Table 2.24.

Table 2.24. Means and standard errors (SE) of fetuses 'Arm movement' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	17.48	4.01	13.29	3.51		
Control	12.62	6.23	15.39	5.45	14.01	4.14
Live	24.73	4.67	7.70	4.09	16.21	3.11
Recording	27.93	6.72	12.56	5.87	20.14	4.46
Noise	4.65	6.14	17.51	5.37	11.08	4.08

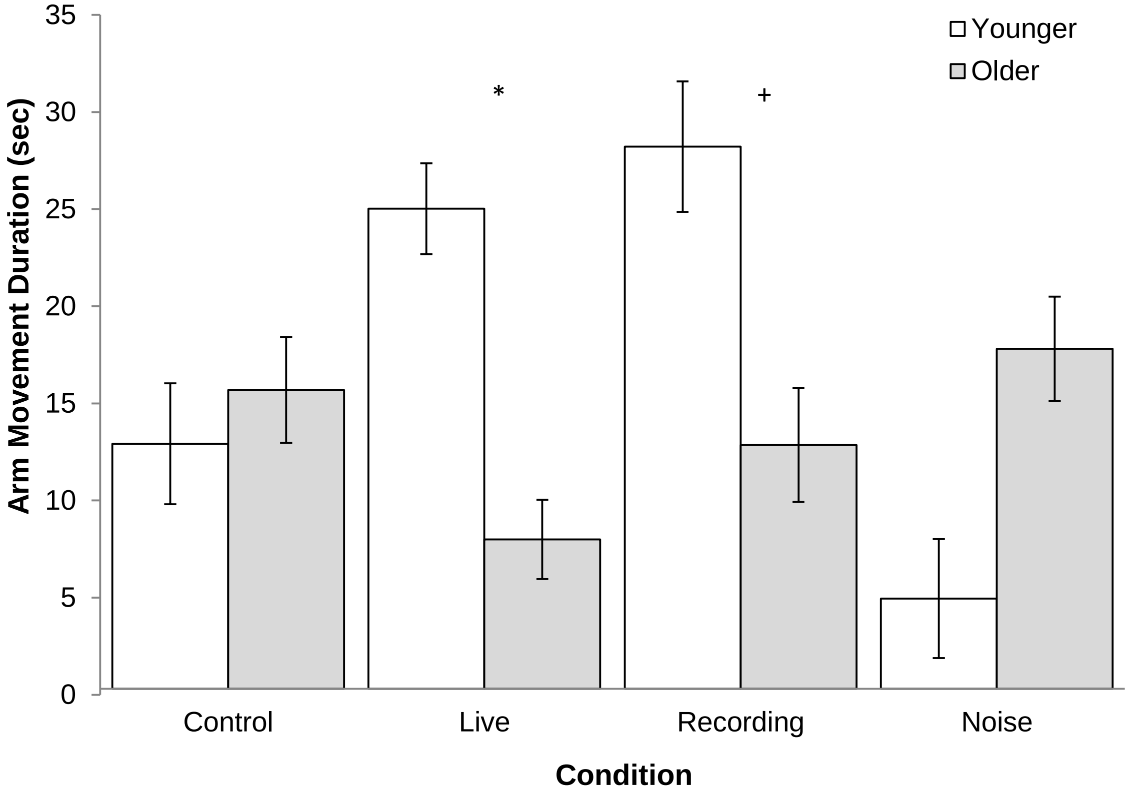

Figure 2.42. Average 'Arm movement' duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

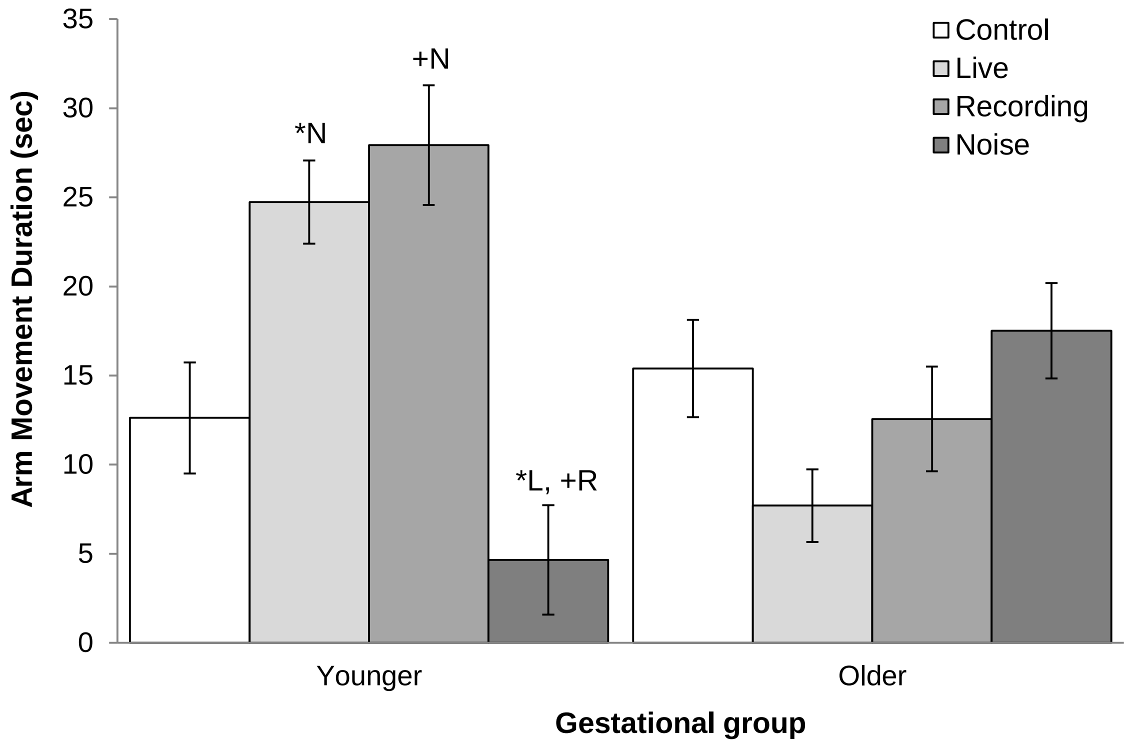

Figure 2.43. Average ‘Arm movement’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

*Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Uterus touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results indicated a significant interaction between Condition and GA, F (2.51, 70.32) = 5.16, p = .005, η_p^2 = .16. A tendency of GA F (1, 28) = 3.18, p = .085, η_p^2 = .10, and no significant main effect of Condition F (2.51, 70.32) = 1.44, p = .241, η_p^2 = .05, were found. In support of this, polynomial contrasts indicated a significant linear trend F (1, 28) = 8.56, p = .007, η_p^2 = .23 of Condition and GA. This finding is qualified by the significant quadratic trend of Condition and GA F (1, 28) = 8.67, p = .006, η_p^2 = .24.

Post-hoc analysis of the interaction showed that younger fetuses (M = 1.85) touch the uterus significantly more in ‘Live’ compared to older fetuses (M = 0.82, p = .013). In the ‘Noise’ condition older fetuses (M = 0.82) touched the uterus significantly more than younger fetuses (M = 0.00, p = .024). Younger fetuses touched the uterus significantly more often in ‘Live’ (M = 1.85) compared to ‘Noise’ (M = 0.00, p = .012), the same tendency was observed for ‘Recording’ (M = 0.92) compared to ‘Noise’ (M = 0.00, p =.078) (see Figures 2.44 and 2.45). Post-hoc analysis of the main effect of GA showed that younger fetuses (M = 0.85) tend to respond more than older fetuses (M = 0.44, p = .085) (see Figure 2.46). No further effects were found. The means and standard errors can be examined in Table 2.25.

Table 2.25. Means and standard errors (SE) of fetuses ‘Uterus touch’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.85	0.17	0.44	0.15		
Control	0.62	0.27	0.24	0.23	0.43	0.18
Live	1.85	0.49	0.12	0.43	0.98	0.33
Recording	0.92	0.31	0.59	0.27	0.76	0.21
Noise	0.00	0.26	0.82	0.23	0.41	0.17

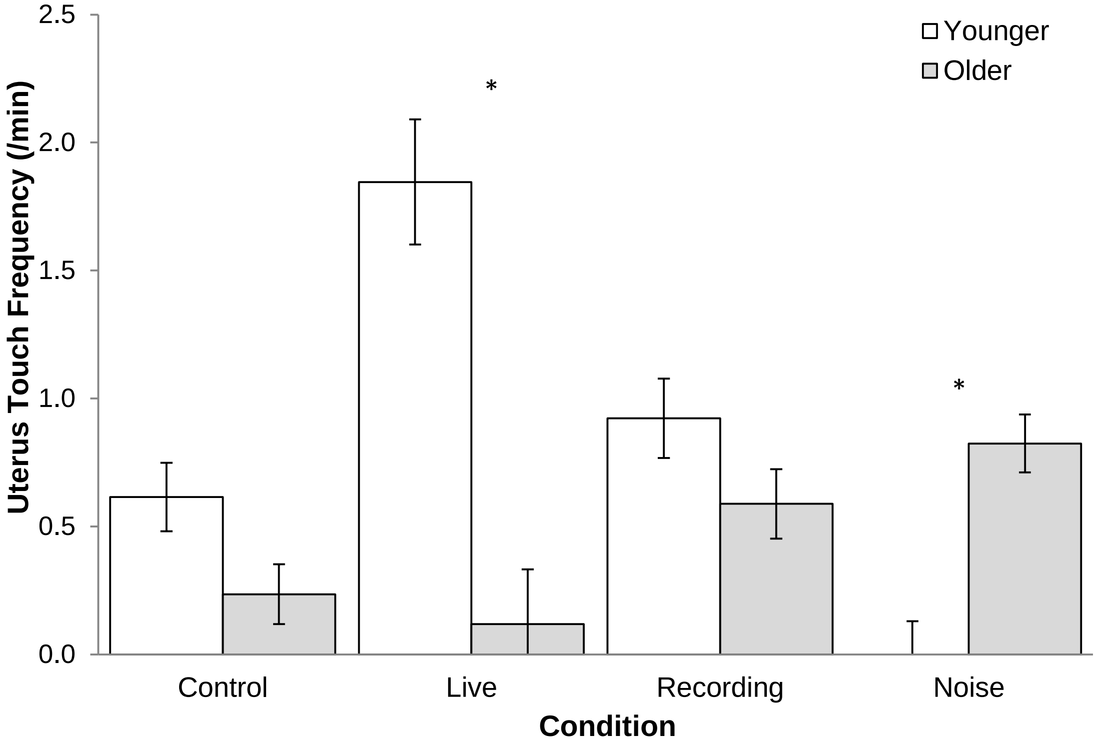

Figure 2.44. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (*< .05).

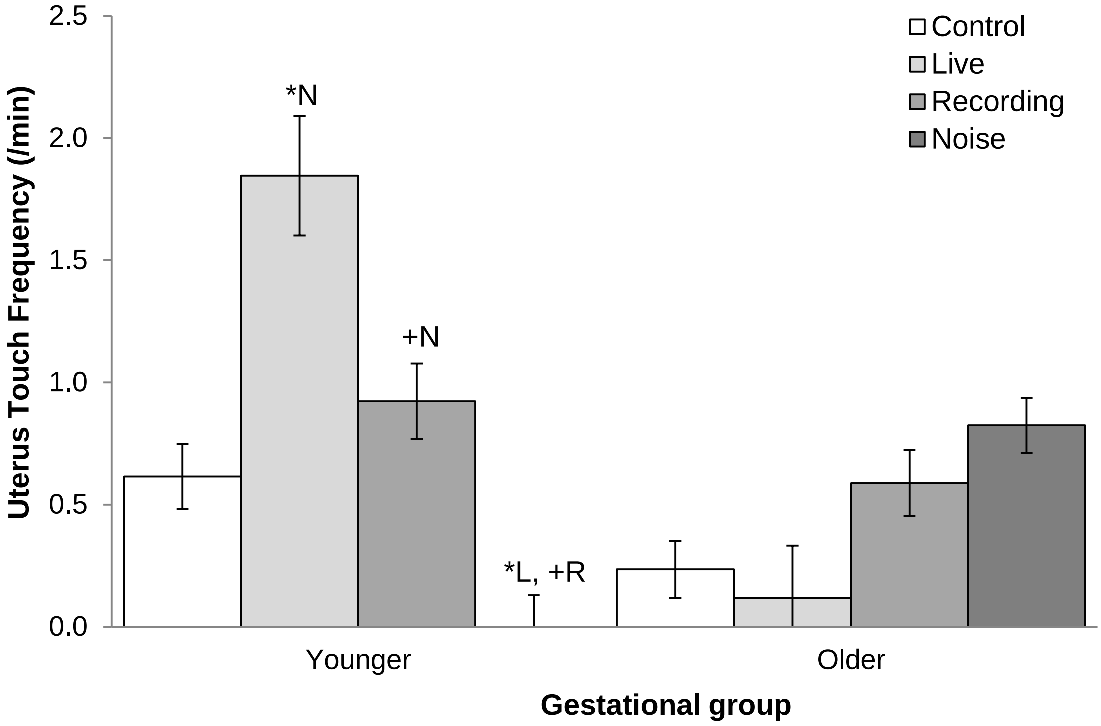

Figure 2.45. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

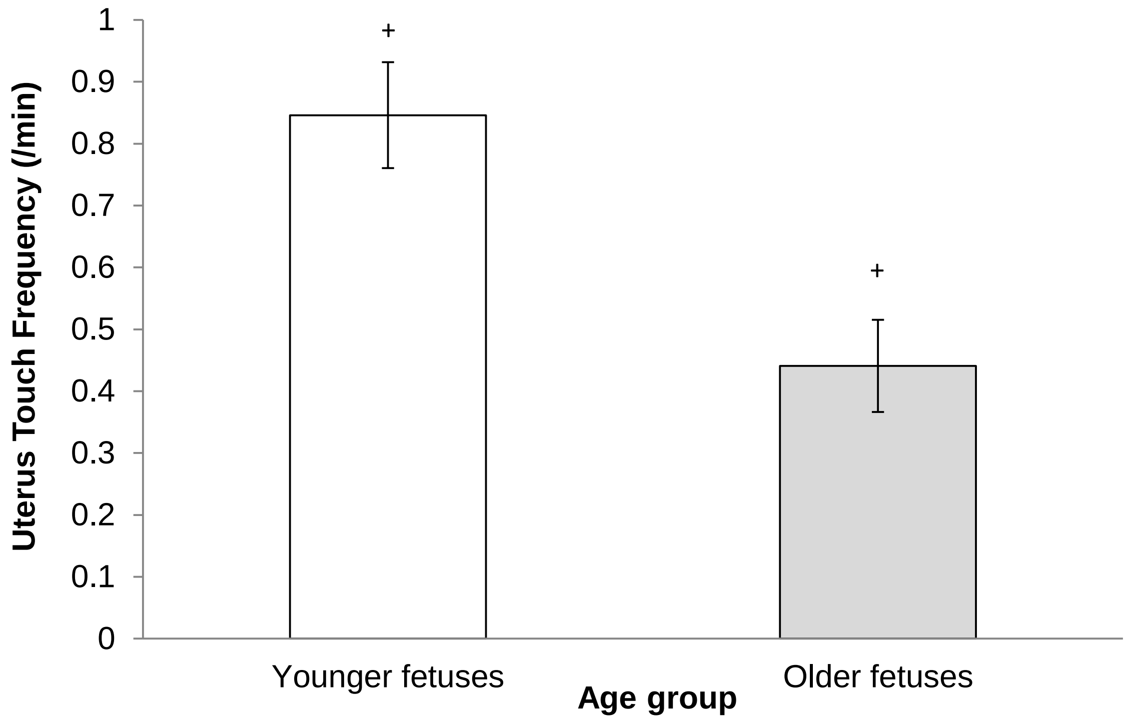

Figure 2.46. Average ‘Uterus touch’ frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Duration*

A mixed design ANOVA, using Huynh-Feldt correction, was conducted to assess differences in ‘Uterus touch’ duration and GA across the four Conditions (Control, Live, Recording, Noise). A significant interaction between Condition and GA, F (3, 83.93) = 3.89, p = .012, η_p^2 = .14 was found. Neither main effects of Condition F (3, 83.93) = 1.52, p = .217, η_p^2 = .05, nor GA F (1, 28) = 1.46, p = .237, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 8.65, p = .007, η_p^2 = .24 of Condition and GA. Post-hoc analysis of the interaction showed that younger fetuses (M = 41.10) touch the uterus significantly longer in ‘Live’ compared to older fetuses (M = 5.88, p = .012). A further tendency can be observed between age groups in ‘Noise’, with older fetuses (M = 22.02) touching longer compared to younger fetuses (M = 0.00, p = .051) (see Figures 2.47 and 2.48). No further effects were found. The means and standard errors can be examined in Table 2.26.

Table 2.26. Means and standard errors (SE) of fetuses 'Uterus touch' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	23.52	5.95	13.98	5.20		
Control	22.01	9.16	5.96	8.01	13.98	6.08
Live	41.10	9.91	5.88	8.67	23.49	6.58
Recording	30.96	11.86	22.05	10.37	26.50	7.88
Noise	0.00	8.12	22.02	7.10	11.01	5.39

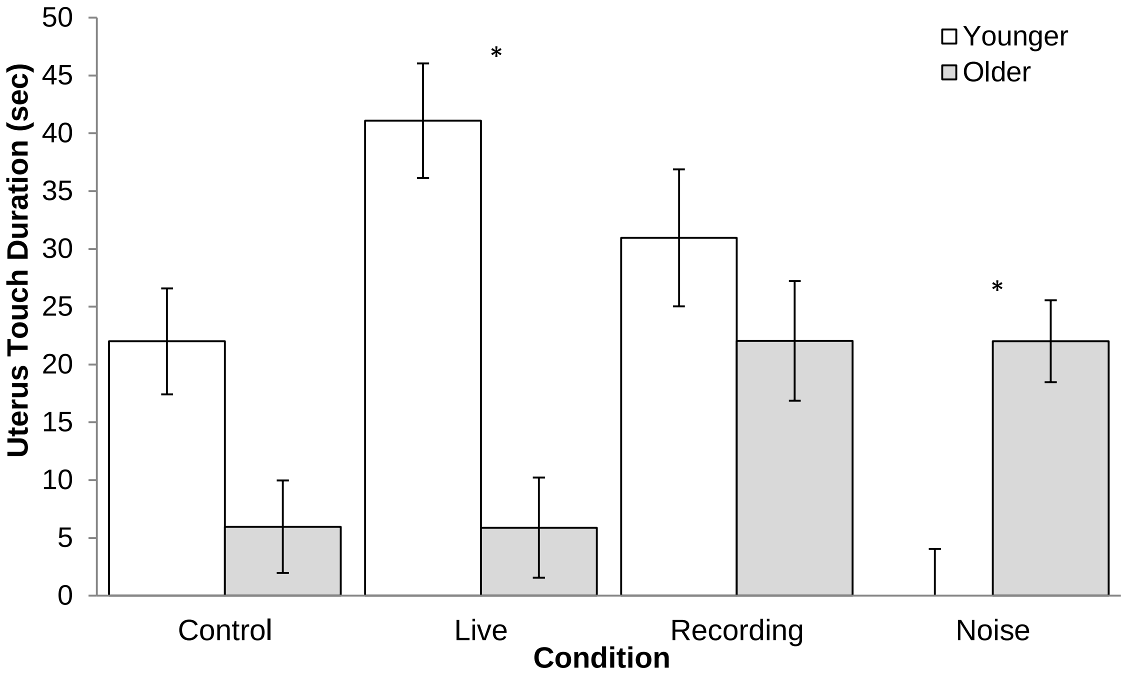

Figure 2.47. Average 'Uterus touch' duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (*< .05).

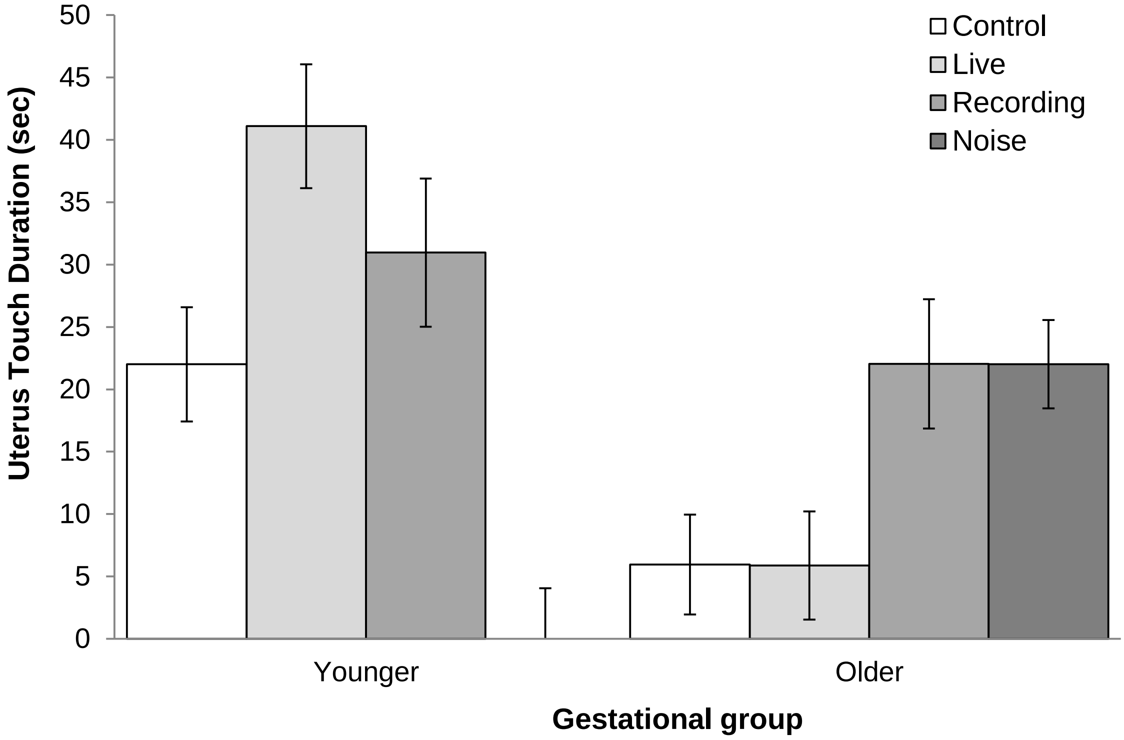

Figure 2.48. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: ‘Head Movement’ Frequency*

A mixed design ANOVA, was conducted to assess differences in ‘Head movement’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). A tendency between Condition and GA, F (3, 84) = 2.61, p = .057, η_p^2 = .09 was found. No main effects of Condition F (3, 84) = 0.36, p = .783, η_p^2 = .01 or GA F (1, 28) = 0.01, p = .912, η_p^2 < .001, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 28) = 7.24, p = .012, η_p^2 = .21 of Condition and GA. No further effects were found. The means and standard errors can be examined in Table 2.27.

Table 2.27. Means and standard errors (SE) of fetuses ‘Head movement’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.65	0.25	0.62	0.22		
Control	0.31	0.44	0.82	0.39	0.57	0.29
Live	0.77	0.46	0.35	0.31	0.56	0.24
Recording	1.39	0.46	0.35	0.40	0.87	0.31
Noise	0.15	0.41	0.94	0.36	0.55	0.27

*Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences in ‘Face press’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). The Condition main effect indicates a trend, F (2.59, 72.41) = 2.76, p = .056, η_p^2 = .09. No main effect of GA F (1, 28) = 0.09, p = .767, η_p^2 < .001, or an interaction F (2.59, 72.41) = 1.40, p = .252, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 28) = 7.52, p = .011, η_p^2 = .21 of Condition, reflecting an increase from ‘Control’ (M = 0.43) to ‘Live’ (M = 0.64), which is followed by a somewhat lower mean from ‘Live’ to ‘Recording’ (M = 0.45) and an increase from ‘Recording’ to ‘Noise’ (M = 0.93).

Post-hoc analysis of the main effect of Condition showed a tendency between ‘Control’ and ‘Noise’ with a higher ‘Face press’ frequency in ‘Noise’ (M = 0.93) compared to ‘Control’ (M = 0.43, p = .080) (see Figure 2.49). No further effects were found. The means and standard errors can be examined in Table 2.28.

Table 2.28. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.65	0.15	0.58	0.18		
Control	0.62	0.22	0.24	0.20	0.43	0.15
Live	0.46	0.27	0.82	0.24	0.64	0.18
Recording	0.31	0.24	0.59	0.21	0.45	0.16
Noise	0.92	0.29	0.94	0.25	0.93	0.19

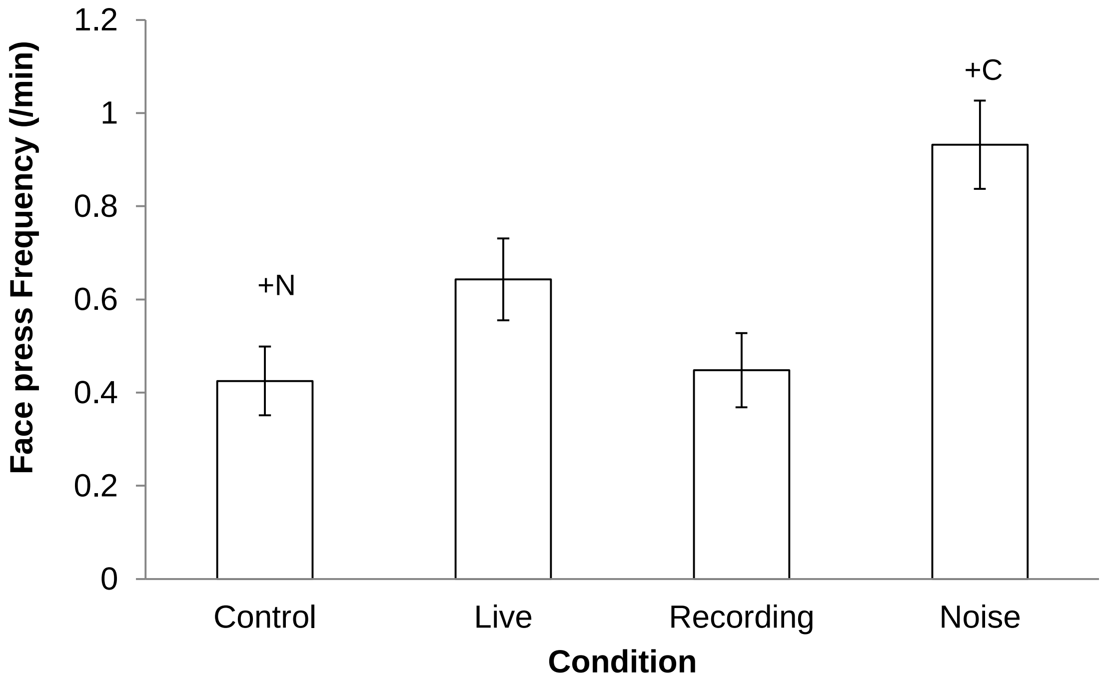

Figure 2.49. Average 'Face press' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Face press' Duration*

A mixed design ANOVA was conducted to assess differences in 'Face press' duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. The Condition main effect indicates a trend, F (2.55, 71.37) = 2.86, p = .051, η_p^2 = .09. No main effect of GA F (1, 28) = 0.13, p = .722, η_p^2 = .01, or an interaction F (2.55, 71.37) = 1.61, p = .200, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 4.24, p = .049, η_p^2 = .13, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 28) = 7.46, p = .011, η_p^2 = .21. Overall, there is a linear increase produced by the means from 'Control' (M = 21.27) to the 'Noise' condition (M = 46.61). However, the 'Recording' condition has a somewhat lower mean (M = 22.40) than the 'Live' condition (M = 30.71) producing the cubic trend.

Post-hoc analysis of the main effect of Condition showed a tendency between 'Control' and 'Noise' with a longer duration of 'Face press' in 'Noise' (M = 46.61) compared to 'Control' (M = 21.27, p = .080) (see Figure 2.50). No further effects were found. The means and standard errors can be examined in Table 2.29.

Table 2.29. Means and standard errors (SE) of fetuses 'Face press' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	28.14	8.84	32.35	7.73		
Control	30.77	11.16	11.77	9.76	21.27	7.41
Live	20.24	12.82	11.21	11.21	30.71	8.52
Recording	15.39	11.98	10.47	10.47	22.40	7.96
Noise	46.15	14.32	12.52	12.52	46.61	9.51

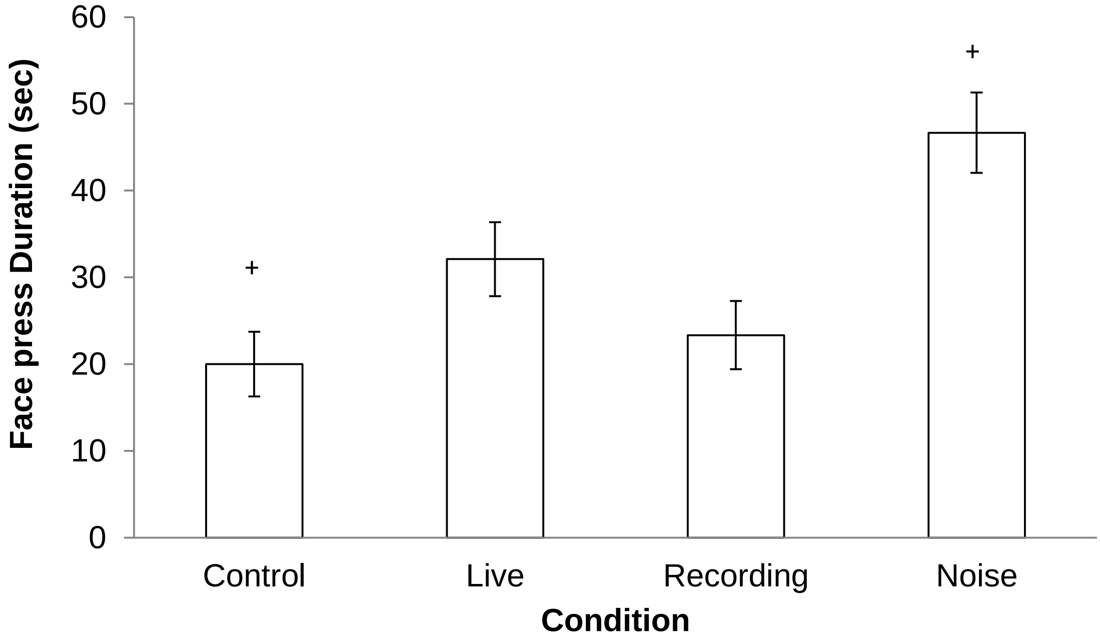

Figure 2.50. Average ‘Face press’ duration (per minute) including standard errors for each condition (.05 ≥+≤ .10).

0-30 Interval analysis combined

*Mixed-design ANOVA Condition*GA: ‘General Movement’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘General movement’ frequency and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effects of Condition *F* (3, 84) = 1.53, *p* = .213, η_p^2 = .05, and GA *F* (1, 28) = 2.57, *p* = .120, η_p^2 = .08. However, a significant interaction between Condition and GA, *F* (3, 84) = 3.78, *p* = .013, η_p^2 = .12, was found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA *F* (1, 28) = 6.09, *p* = .020, η_p^2 = .18. Post-hoc analysis of the interaction showed a significant difference in ‘Recording’ between younger and older fetuses, with younger fetuses (M = 8.92) displaying more ‘General movements’ compared to older fetuses (M = 3.41, *p* = .011). A marginally significant difference was found for ‘Noise’ between age groups, with older fetuses (M = 5.77) exhibiting more ‘General movements’ compared to younger fetuses (M = 2.00, *p* = .052). Younger fetuses showed further significant differences between ‘Recording’ and ‘Noise’, with increased ‘General movements’ in ‘Recording’ (M = 8.92) compared to ‘Noise’ (M = 2.00, *p* =.004) (see Figure 2.51 and 2.52). No further effects were found. The means and standard errors can be examined in Table 2.30.

Table 2.30. Means and standard errors (SE) of fetuses ‘General movement’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	6.00	0.80	4.29	0.70		
Control	5.23	1.37	3.29	1.20	4.26	0.91
Live	7.85	1.84	4.71	1.61	6.28	1.22
Recording	8.92	1.52	3.41	1.33	6.17	1.01
Noise	2.00	1.40	5.77	1.22	3.88	0.93

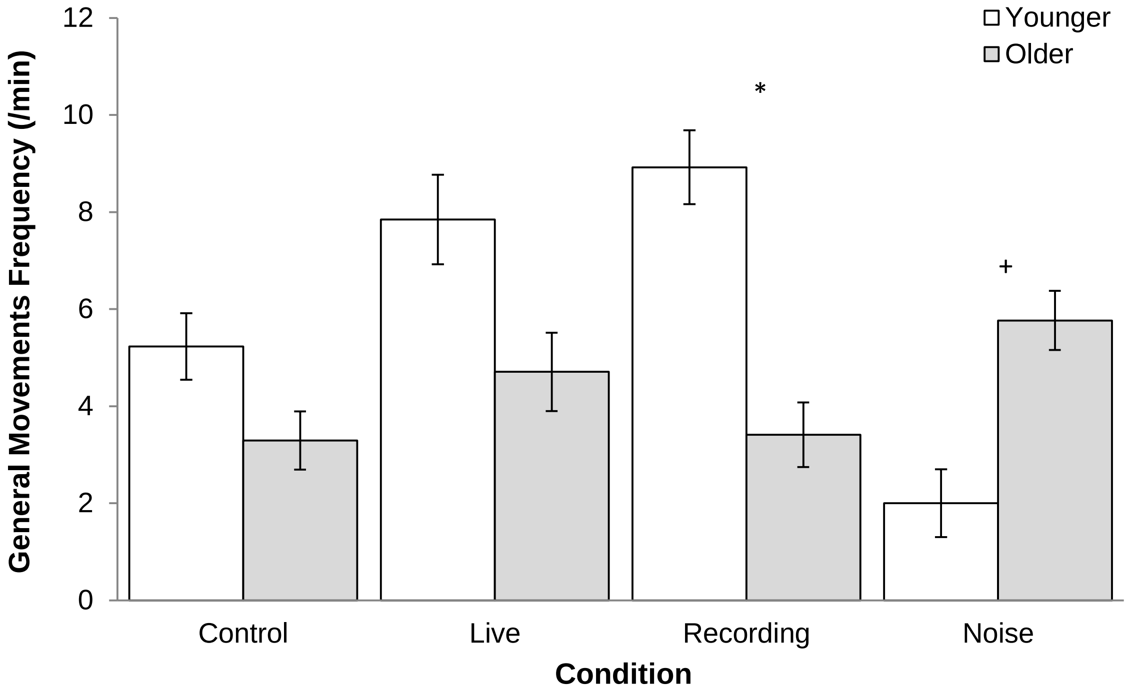

Figure 2.51. Average ‘General movement’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (* < .05).

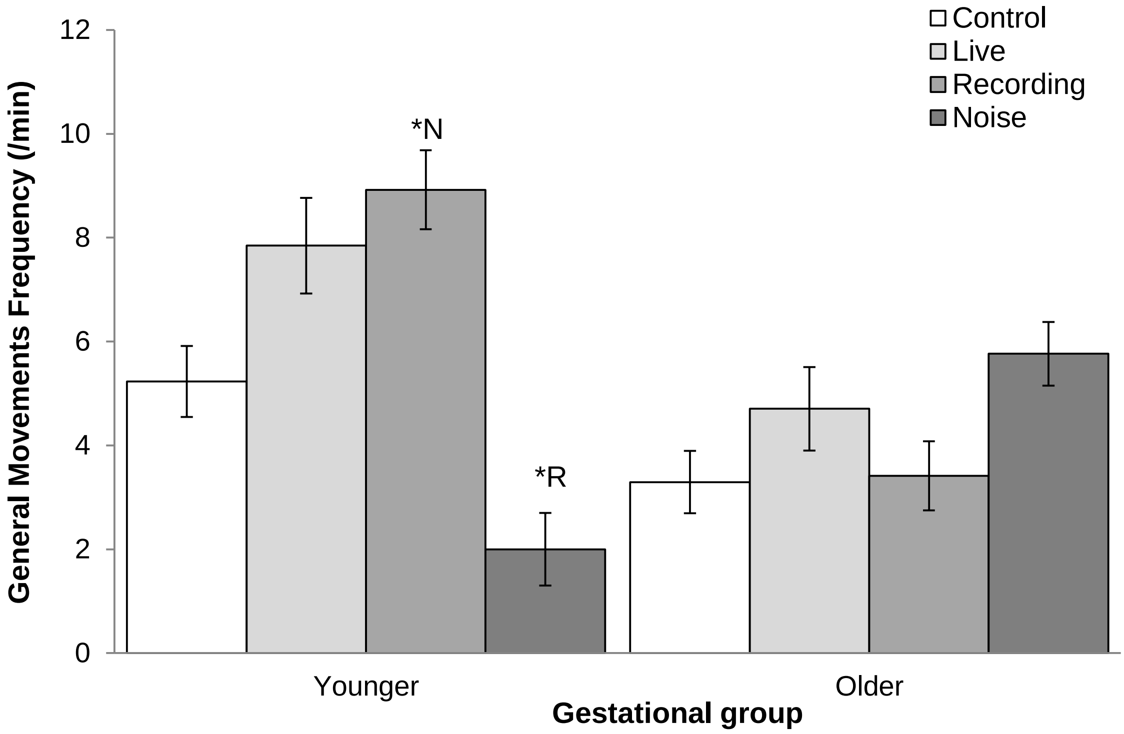

Figure 2.52. Average ‘General movement’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘General Movement’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘General movement’ duration and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effects of Condition F (3, 84) = 1.17, p = .327, η_p^2 = .04, and GA F (1, 28) = 0.90, p = .352, η_p^2 = .03. However, a marginally significant interaction between Condition and GA, F (3, 84) = 2.55, p = .061, η_p^2 = .08, was found. In support of this polynomial contrasts indicated a marginally significant quadratic trend of Condition and GA F (1, 28) = 4.19, p = .050, η_p^2 = .13.

Post-hoc analysis of the interaction showed a marginally significant difference in ‘Live’ between younger and older fetuses, with younger fetuses (M = 3.55) displaying longer ‘General movements’ compared to older fetuses (M = 1.43, p

= .052). A marginally significant difference was revealed for younger fetuses in between ‘Live’ and ‘Noise’, with longer movements in ‘Live’ (M = 3.55) compared to ‘Noise’ (M = 1.01, *p* = .092) (see Figures 2.53 and 2.54). No further effects were found. The means and standard errors can be examined in Table 2.31.

Table 2.31. Means and standard errors (SE) of fetuses ‘General movement’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.59	0.54	1.92	0.47		
Control	1.94	0.74	1.84	0.65	1.89	0.49
Live	3.55	0.78	1.43	0.69	2.49	0.52
Recording	3.87	1.02	1.98	0.89	2.93	0.68
Noise	1.01	0.88	2.41	0.77	1.71	0.59

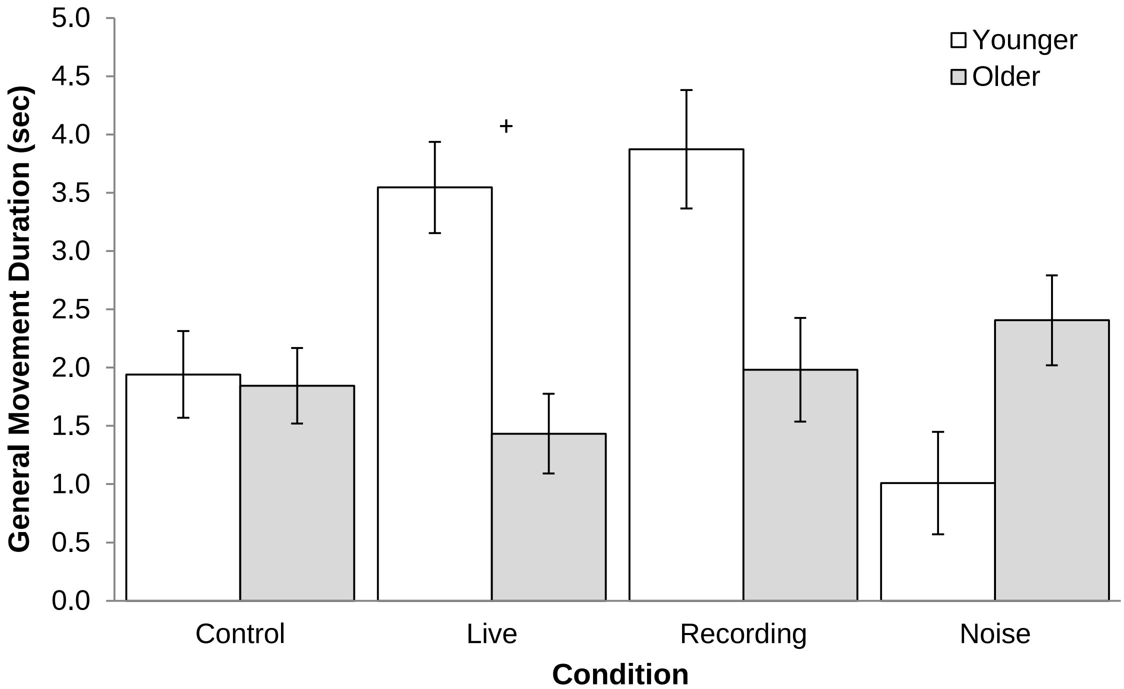

Figure 2.53. Average ‘General movement’ duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10).

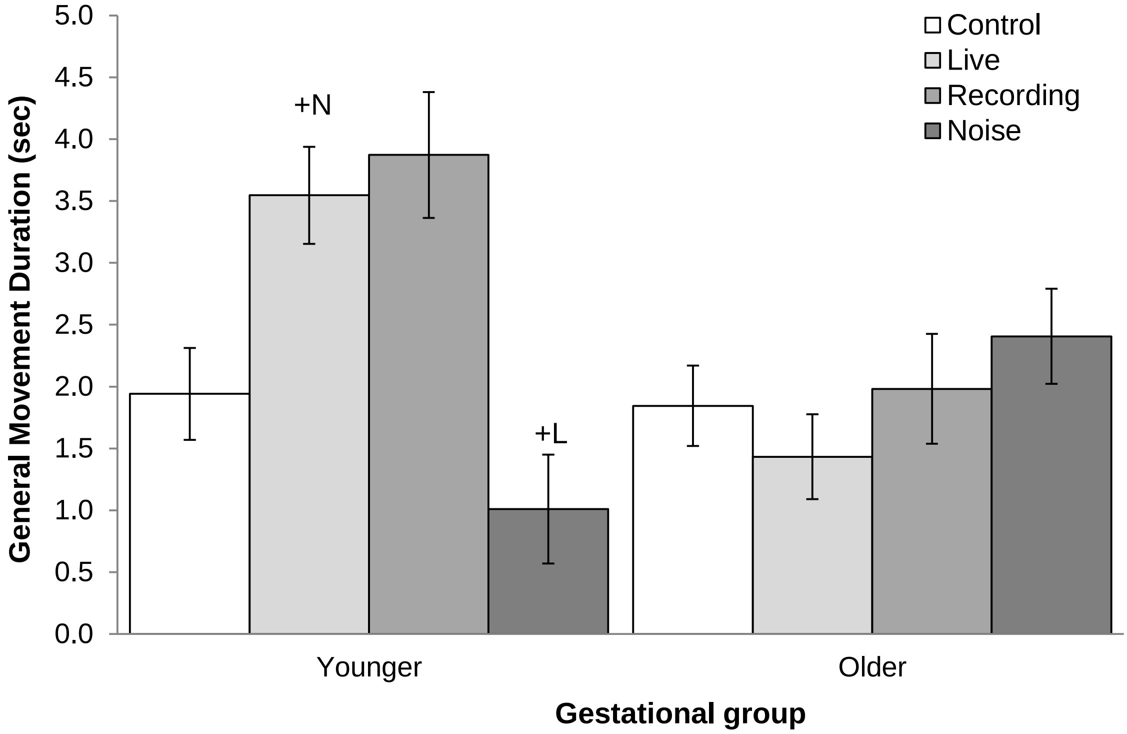

Figure 2.54. Average 'General movement' duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'External Touch' Frequency*

A mixed design ANOVA was conducted to assess differences in 'External touch' frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results showed no significant main effects of Condition F (3, 84) = 1.33, p = .271, η_p^2 = .05, and GA F (1, 28) = 0.83, p = .372, η_p^2 = .03. However, a significant interaction between Condition and GA, F (3, 84) = 2.90, p = .040, η_p^2 = .09, was found. In support of this polynomial contrasts indicated a significant linear trend of Condition and GA F (1, 28) = 7.88, p = .009, η_p^2 = .22.
Post-hoc analysis of the interaction showed a marginally significant difference in 'Live', with younger fetuses (M = 2.31) increasing 'External touch' frequency compared to older fetuses (M = 0.94, p = .084). A significant difference was found for older fetuses between 'Control' and 'Noise', with more 'External touch' in 'Noise' (M = 1.77) compared to 'Control' (M = 0.47, p = .031) (see Figure 2.55

and 2.56). No further effects were found. The means and standard errors can be examined in Table 2.32.

Table 2.32. Means and standard errors (SE) of fetuses ‘External touch’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.42	0.28	1.09	0.24		
Control	1.23	0.42	0.47	0.37	0.85	0.28
Live	2.31	0.57	0.94	0.50	1.62	0.38
Recording	1.23	0.44	1.18	0.38	1.20	0.29
Noise	0.92	0.38	1.77	0.33	1.34	0.25

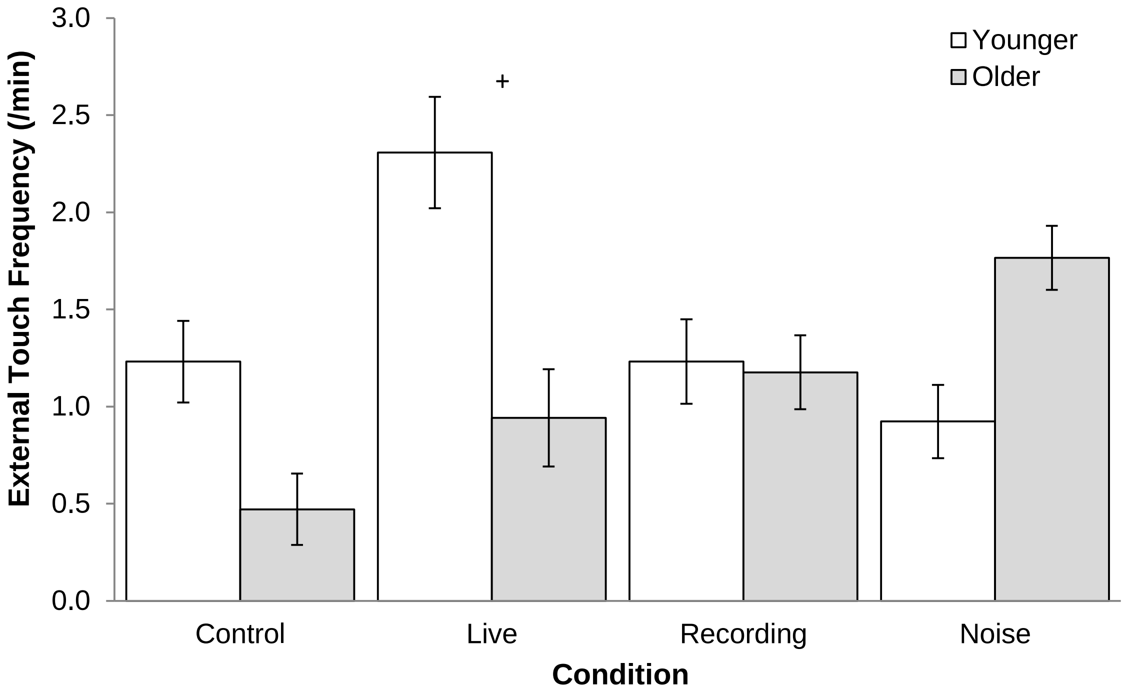

Figure 2.55. Average ‘External touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

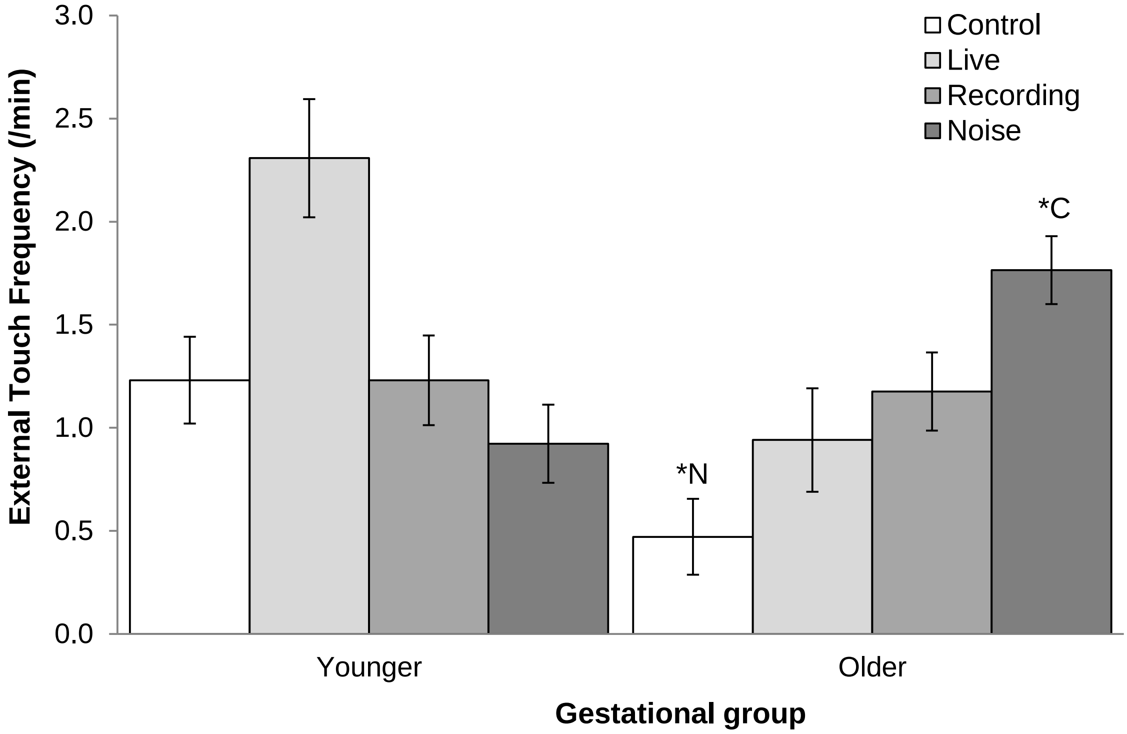

Figure 2.56. Average ‘External touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

0-60 Interval analysis

Repeated-measures ANOVA Condition: ‘Face press’ Frequency

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in frequency of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). Results indicate that there was a trend in ‘Face press’ frequency between the four Conditions F (2.53, 73.40) = 2.89, p = .050, η_p^2 = .09. Examination of these means suggests that fetuses ‘Face press’ frequency changed depending on Condition. Polynomial contrasts indicated, in support of this, there was a significant linear trend, F (1, 29) = 4.62, p = .040, η_p^2 = .14. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.37, p = .007, η_p^2 = .22. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.20) to the ‘Noise’ condition (M = 0.47). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.23) than the ‘Live’ condition (M = 0.33) producing the cubic trend. Post-hoc analysis showed a trend between ‘Noise’ (M = 0.47) and ‘Control’, with fetuses increasing ‘Face press’ frequency in the ‘Noise’ condition compared to ‘Control’ (M = 0.20, *p* = .053) (see Figure 2.57). No further effects were found. The means and standard errors can be examined in Table 2.33.

Table 2.33. Means and standard errors (SE) on the frequency of fetuses facial touch of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	0.20	0.33	0.23	0.47
SE	0.07	0.09	0.08	0.09

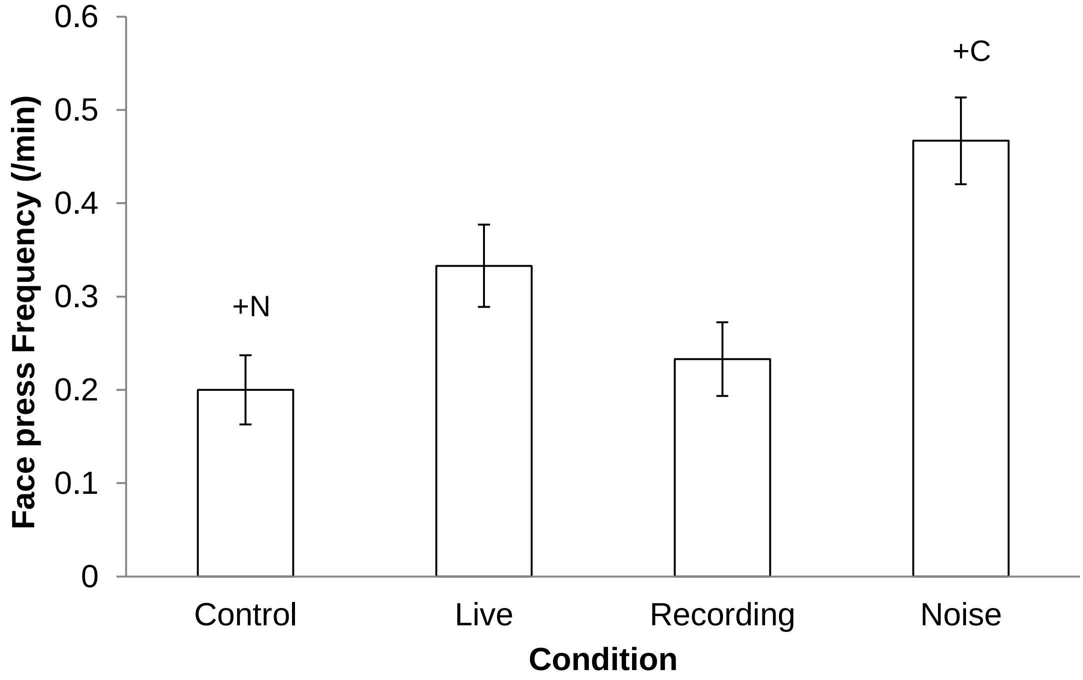

Figure 2.57. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in duration of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). Results indicated that there was a significant difference in ‘Face press’ duration between the four Conditions F (2.5, 72.46) = 3.07, p = .041, η_p^2 = .10.

Examination of these means suggests that ‘Face press’ duration differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.02, p = .033, η_p^2 = .15. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.69, p = .006, η_p^2 = .23. Overall, there is a linear increase produced by the means from ‘Control’ (M = 19.36) to the ‘Noise’ condition (M = 46.67). However, the ‘Recording’ condition has a somewhat lower mean (M = 23.33) than the ‘Live’ condition (M = 32.72) producing the cubic trend.

Post-hoc analysis showed a significant difference between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ duration in the ‘Noise’ (M = 46.67) condition compared to ‘Control’ (M = 19.36, p = .044) (see Figure 2.58). No further effects were found. The means and standard errors can be examined in Table 2.34.

Table 2.34. Means and standard errors (SE) on the duration of fetuses facial touch of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	19.36	32.72	23.33	46.67
SE	7.21	8.61	7.85	9.26

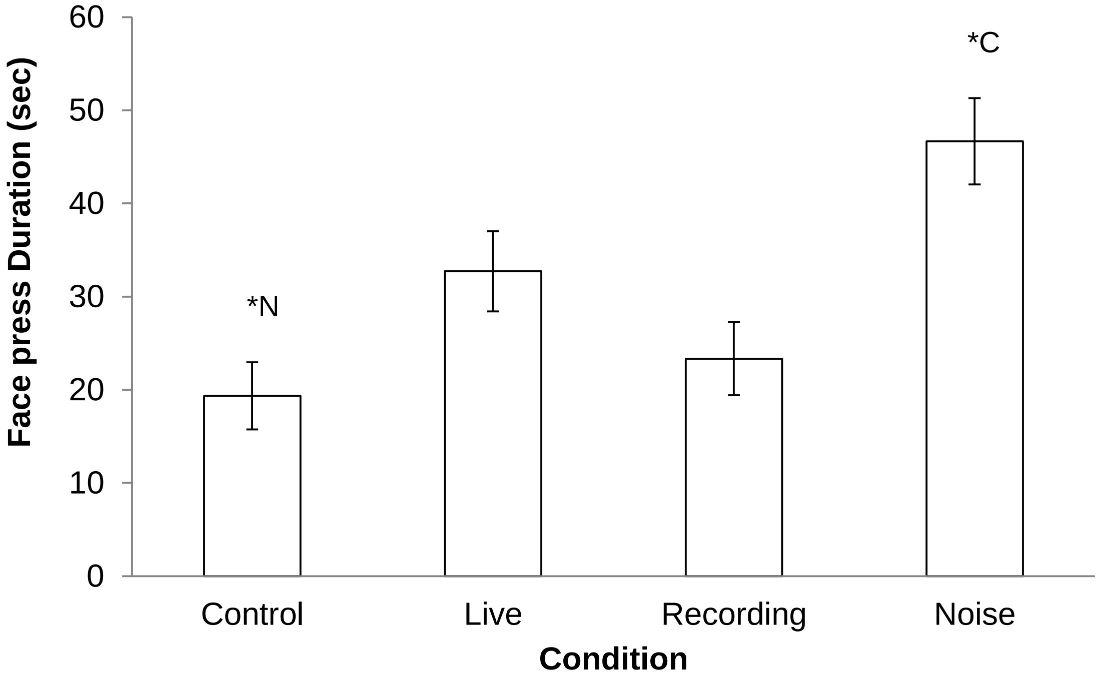

Figure 2.58. Average ‘Face press’ duration (in seconds) including standard errors for each condition (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Arm Movement’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Arm movement’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a significant interaction between Condition and GA, F (3, 84) = 3.39, p = .022, η_p^2 = .11. No main effects of Condition F (3, 84) = 1.09, p = .360, η_p^2 = .04, or a main effect of GA F (1, 28) = 2.50, p = .125, η_p^2 = .08, were found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition F (1, 28) = 7.40, p = .011, η_p^2 = .21. Post-hoc analysis of the interaction showed a significant difference of younger fetuses displaying more ‘Arm movements’ in ‘Live’ (M = 5.00, p = .031) and tendencies in ‘Recording’ (M = 4.46, p = .073), and ‘Noise’ conditions (M = 1.85, p = .092) compared to older fetuses (‘Live’: M = 2.35, ‘Recording’: M = 2.65, ‘Noise’: M = 3.41). No significant differences were observed in ‘Control’ between age groups (young: M = 3.23, old: M = 2.47). Younger fetuses displayed significantly more ‘Arm movements’ in ‘Live’ (M = 5.00) compared to ‘Noise’ (M = 1.85, p = .028), the same tendency can be observed for

'Recording' (M = 4.46) compared to 'Noise' (M = 1.85, *p* = .082) (see Figures 2.59 and 2.60). No further effects were found. The means and standard errors can be examined in Table 2.35.

Table 2.35. Means and standard errors (SE) of fetuses 'Arm movement' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.63	0.38	2.72	0.44		
Control	3.23	0.82	2.47	0.71	2.85	0.54
Live	5.00	0.88	2.35	0.77	3.68	0.58
Recording	4.46	0.73	2.65	0.64	3.55	0.49
Noise	1.85	0.68	3.41	0.59	2.63	0.45

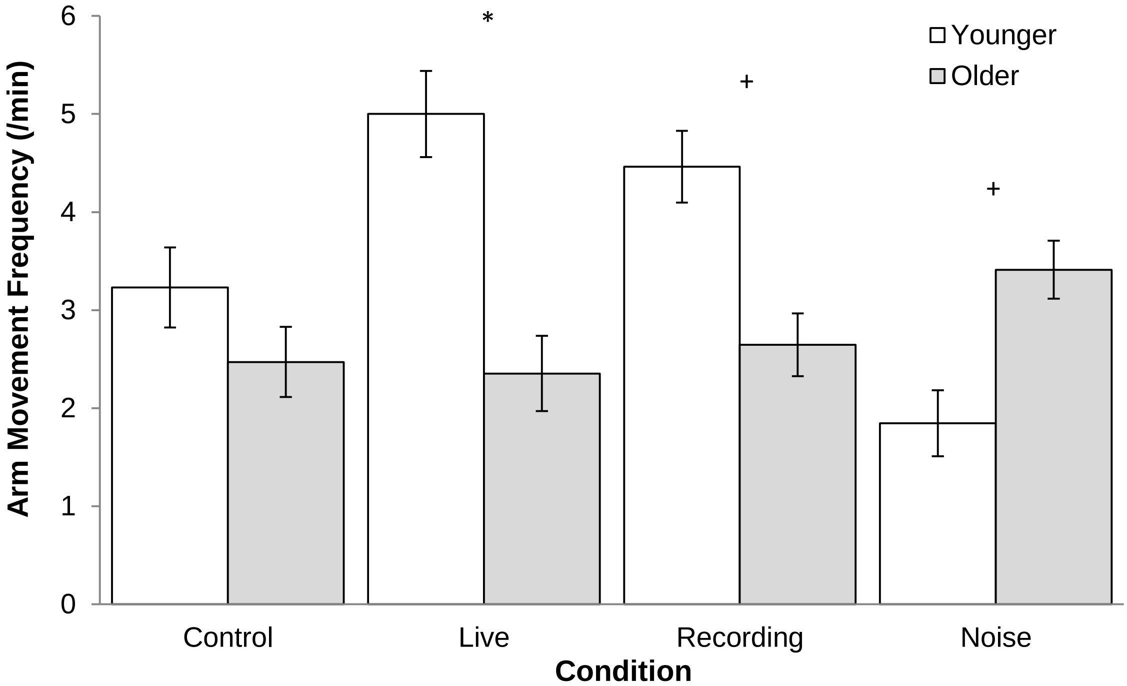

Figure 2.59. Average 'Arm movement' frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

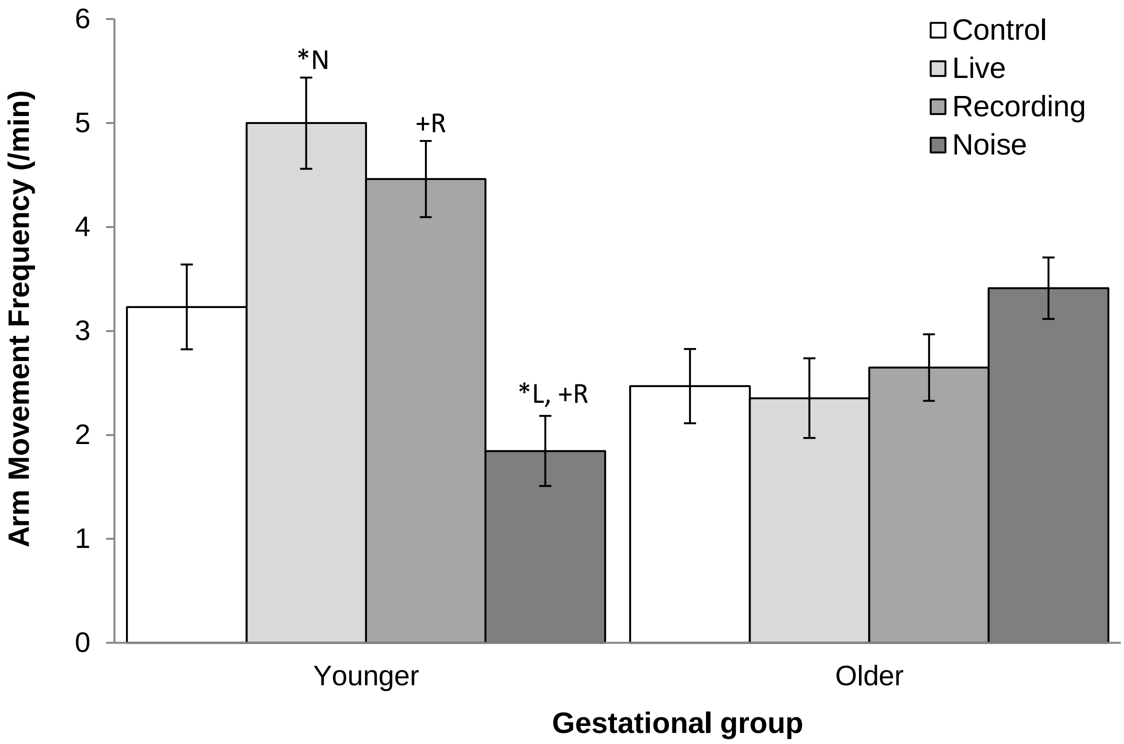

Figure 2.60. Average ‘Arm movement’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

*Mixed-design ANOVA Condition*GA: ‘Arm Movement’ Duration*

A mixed ANOVA was conducted to assess differences in ‘Arm movement’ duration and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a significant interaction between Condition and GA, F (3, 84) = 3.76, p = .014, η_p^2 = .12. No main effects of Condition F (3, 84) = 0.94, p = .427, η_p^2 = .03 or GA F (1, 28) = 0.23, p = .633, η_p^2 = .01, were found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 28) = 5.90, p = .022, η_p^2 = .17.

Post-hoc analysis of the interaction showed that younger fetuses (M = 22.79) moved significantly longer in ‘Live’ compared to older fetuses (M = 8.64, p = .017) (see Figure 2.61 and 2.62). No further effects were found. The means and standard errors can be examined in Table 2.36.

Table 2.36. Means and standard errors (SE) of fetuses ‘Arm movement’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	18.25	3.91	15.75	3.42		
Control	16.67	6.21	18.91	5.43	17.79	4.13
Live	22.79	4.19	8.64	3.67	15.72	2.79
Recording	25.09	5.41	15.96	4.73	20.53	3.60
Noise	8.46	5.80	19.47	5.07	13.97	3.85

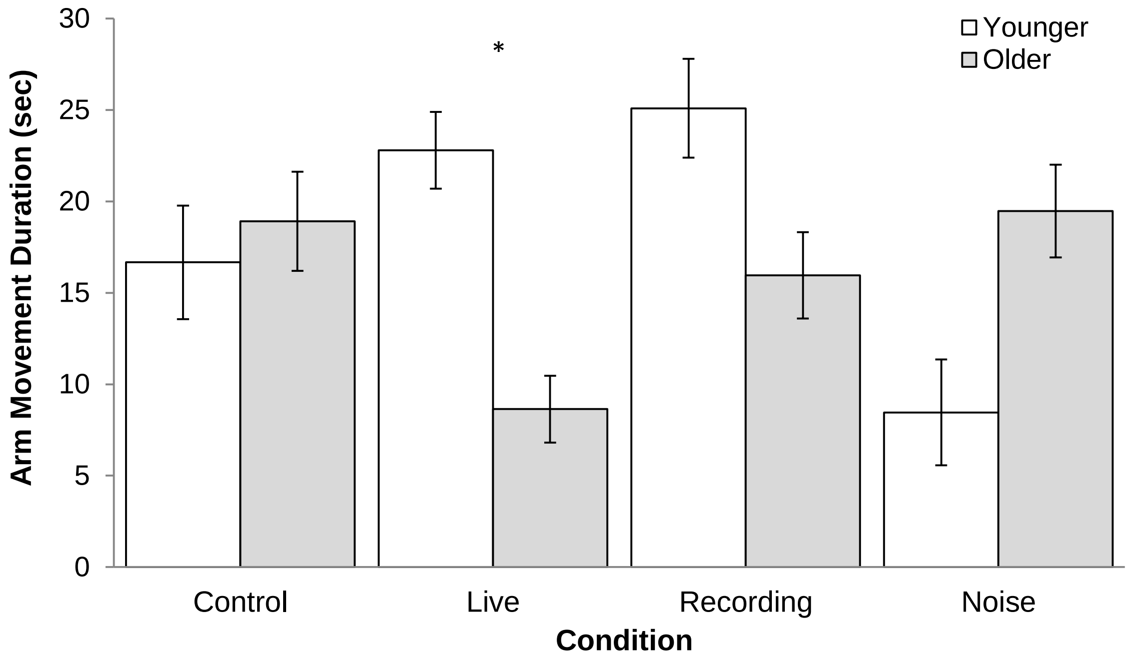

Figure 2.61. Average ‘Arm movement’ duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (*< .05).

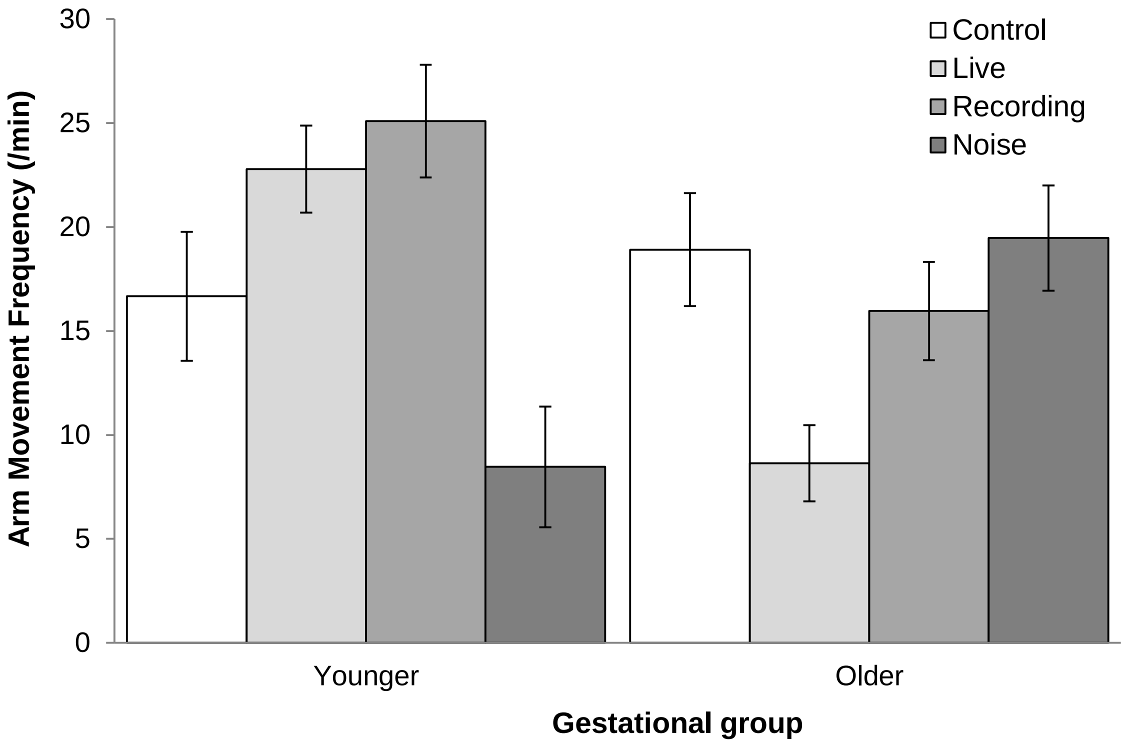

Figure 2.62. Average ‘Arm movement’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: ‘Body Touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in body touch frequency and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. Results showed a tendency for an interaction between Condition and GA, F (1.68, 47.17) = 2.63, p = .091, η_p^2 = .09. No main effects of Condition F (1.68, 47.17) = 0.63, p = .511, η_p^2 = .02, or GA F (1, 28) = 0.90, p = .351, η_p^2 = .03, were found. In support of this polynomial contrasts of the interaction indicated a significant cubic trend F (1, 28) = 7.85, p = .009, η_p^2 = .22. Post-hoc analysis of the interaction showed a tendency in the ‘Noise’ condition for an increased frequency of body touch for older (M = 1.24) compared to younger fetuses (M = 0.08, p = .097) (see Figure 2.63 and 2.64). No further effects were found. The means and standard errors can be examined in Table 2.37.

Table 2.37. Means and standard errors (SE) of fetuses body touch frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.35	0.16	0.54	0.14		
Control	0.46	0.20	0.24	0.17	0.35	0.13
Live	0.23	0.15	0.35	0.13	0.29	0.10
Recording	0.62	0.25	0.35	0.22	0.48	0.17
Noise	0.08	0.51	1.24	0.44	0.66	0.34

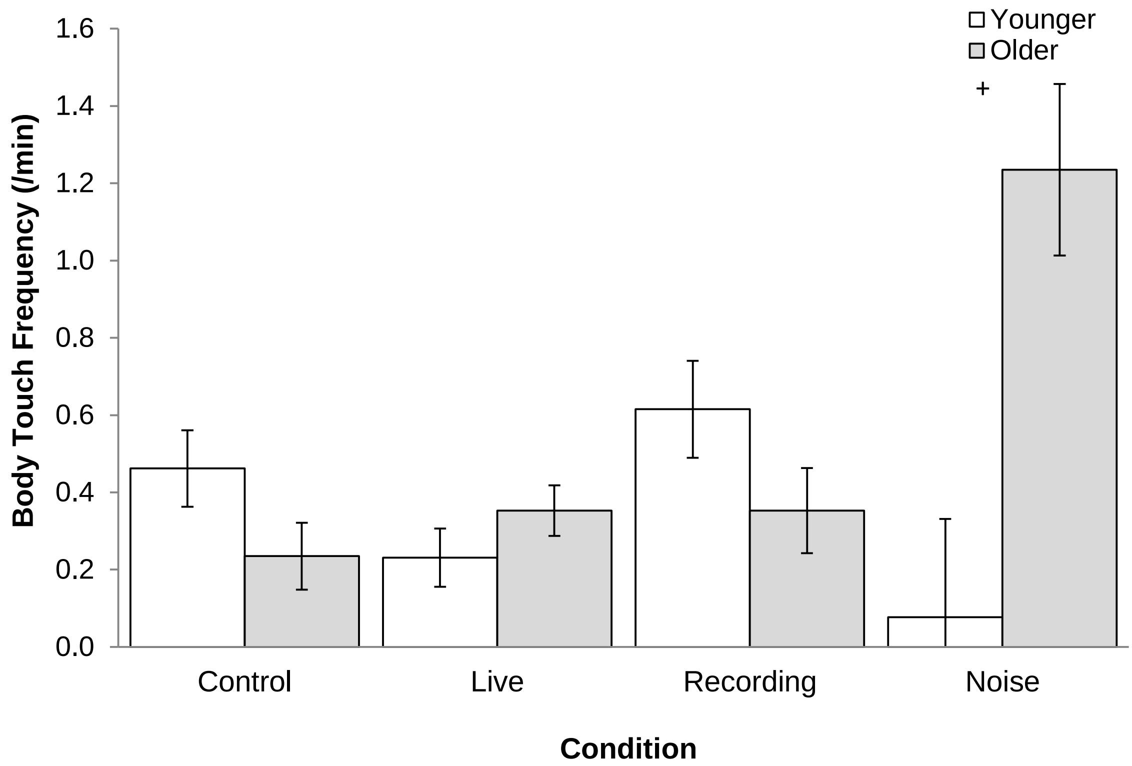

Figure 2.63. Average body touch frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10).

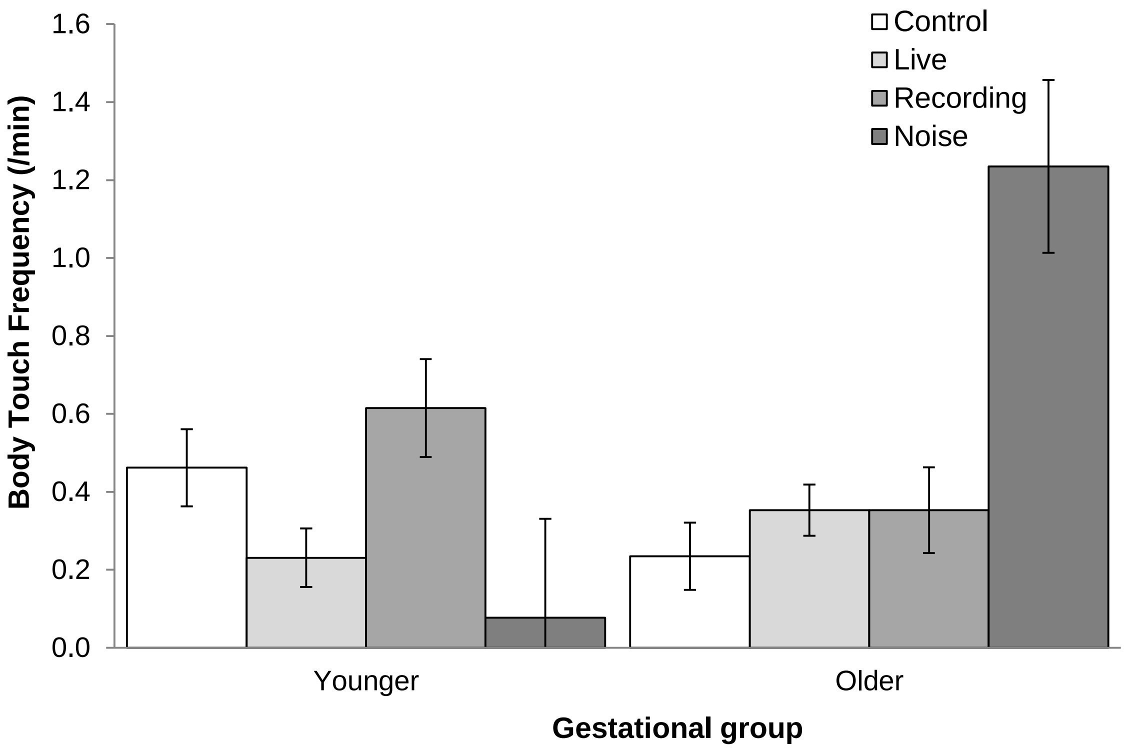

Figure 2.64. Average ‘Body touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: ‘Face Touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Face touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results showed a tendency of an interaction between Condition and GA, F (3, 84) = 2.60, p = .058, η_p^2 = .09. No main effects of Condition F (3, 84) = 0.34, p = .797, η_p^2 = .01, or GA F (1, 28) = 1.33, p = .258, η_p^2 = .05, were found. In support of this polynomial contrasts of the interaction indicated a significant quadratic trend F (1, 28) = 6.75, p = .015, η_p^2 = .19.

Post-hoc analysis of the interaction showed a significant increase of ‘Face press’ frequency in the ‘Live’ condition for younger (M = 1.94) compared to older fetuses (M = 0.77, p = .034) and a significant increase for younger (M = 1.62) compared to older fetuses (M = 0.65, p = .047) in the ‘Recording’ condition (see Figure 2.65 and 2.66). No further effects were found. The means and standard errors can be examined in Table 2.38.

Table 2.38. Means and standard errors (SE) of fetuses 'Face touch' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.33	0.24	0.96	0.21		
Control	0.92	0.35	1.06	0.31	0.99	0.24
Live	1.92	0.39	0.77	0.34	1.34	0.26
Recording	1.62	0.35	0.65	0.31	1.13	0.23
Noise	0.85	0.52	1.35	0.45	1.10	0.34

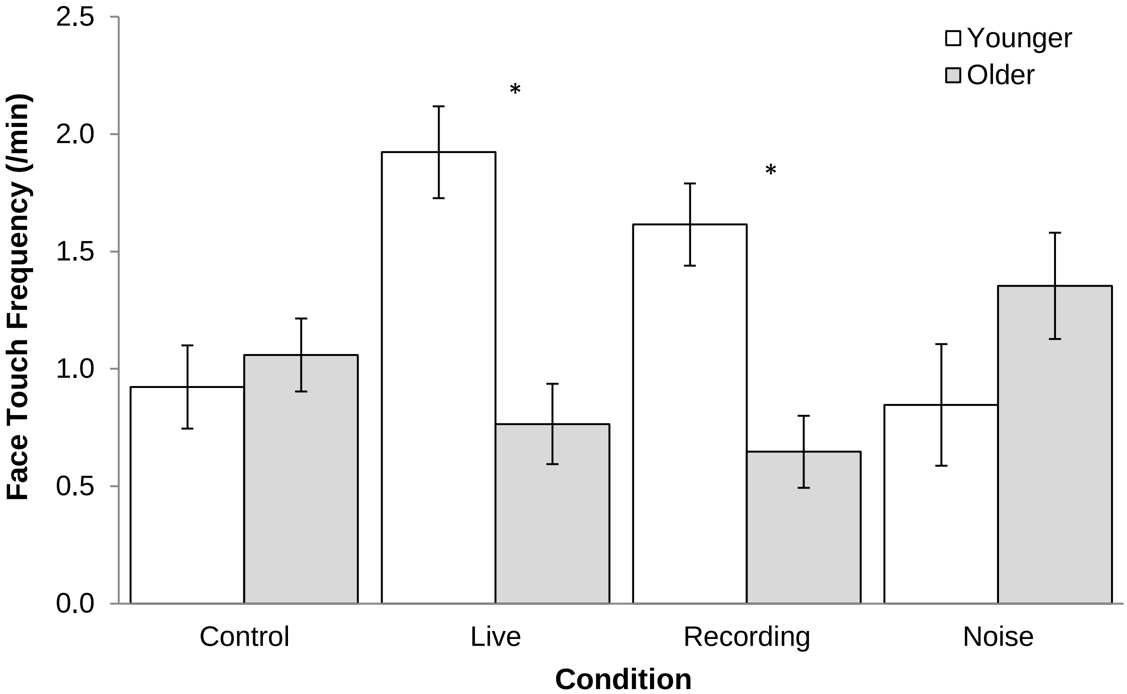

Figure 2.65. Average 'Face touch' frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (*< .05).

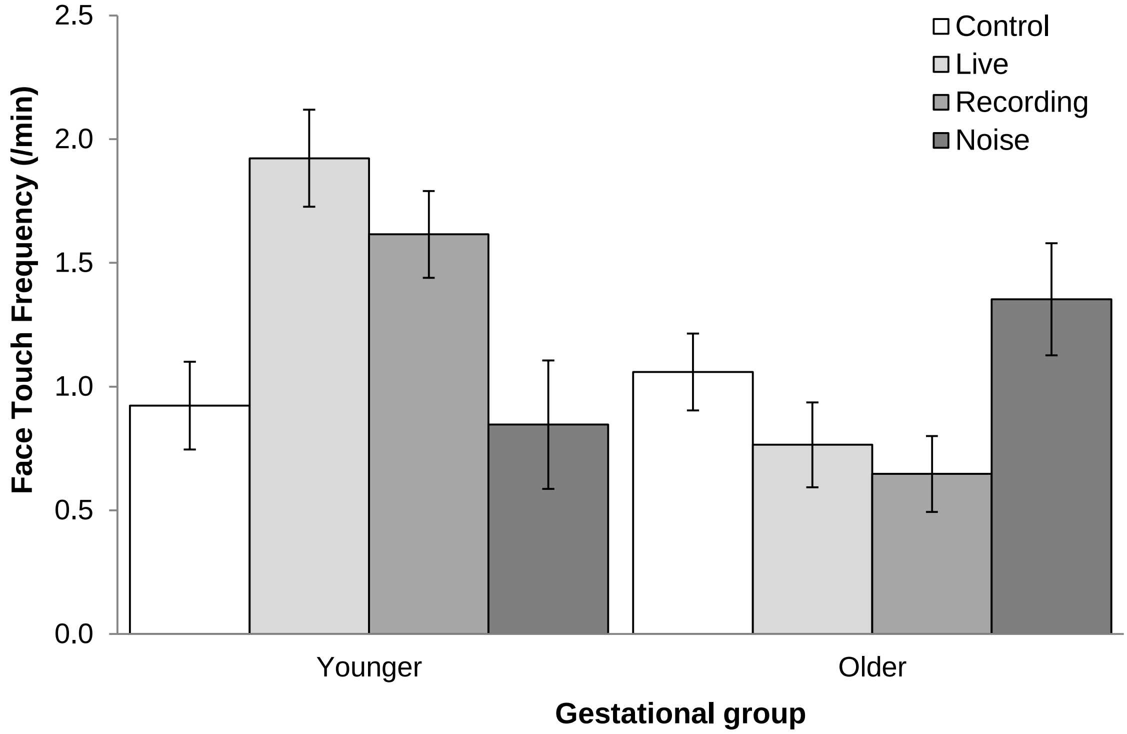

Figure 2.66. Average ‘Face touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: ‘Uterus Touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Uterus touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a significant interaction between Condition and GA, F (3, 84) = 5.19, p = .002, η_p^2 = .16. No main effects of Condition F (3, 84) = 1.06, p = .370, η_p^2 = .04, or GA F (1, 28) = 1.07, p = .309, η_p^2 = .04, were found. In support of this, polynomial contrasts of the interaction indicated a significant linear trend F (1, 28) = 6.55, p = .016, η_p^2 = .19. This finding is qualified by the significant quadratic trend of Condition and GA F (1, 28) = 6.45, p = .017, η_p^2 = .19.

Post-hoc analysis of the interaction showed that younger fetuses (M = 1.69) touch the uterus significantly more in ‘Live’ compared to older fetuses (M = 0.18, p = .010). In the ‘Noise’ condition older fetuses (M = 0.94) tended to touch the uterus more than younger fetuses (M = 0.08, p = .065). Younger fetuses touched the uterus significantly more often in ‘Live’ (M = 1.69) compared to

'Noise' (M = 0.08, p = .034) (see Figures 2.67 and 2.68). No further effects were found. The means and standard errors can be examined in Table 2.39.

Table 2.39. Means and standard errors (SE) of fetuses 'Uterus touch' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.71	0.15	0.50	0.13		
Control	0.54	0.26	0.35	0.23	0.45	0.17
Live	1.69	0.41	0.18	0.46	0.93	0.27
Recording	0.54	0.24	0.53	0.21	0.53	0.16
Noise	0.08	0.34	0.94	0.30	0.51	0.23

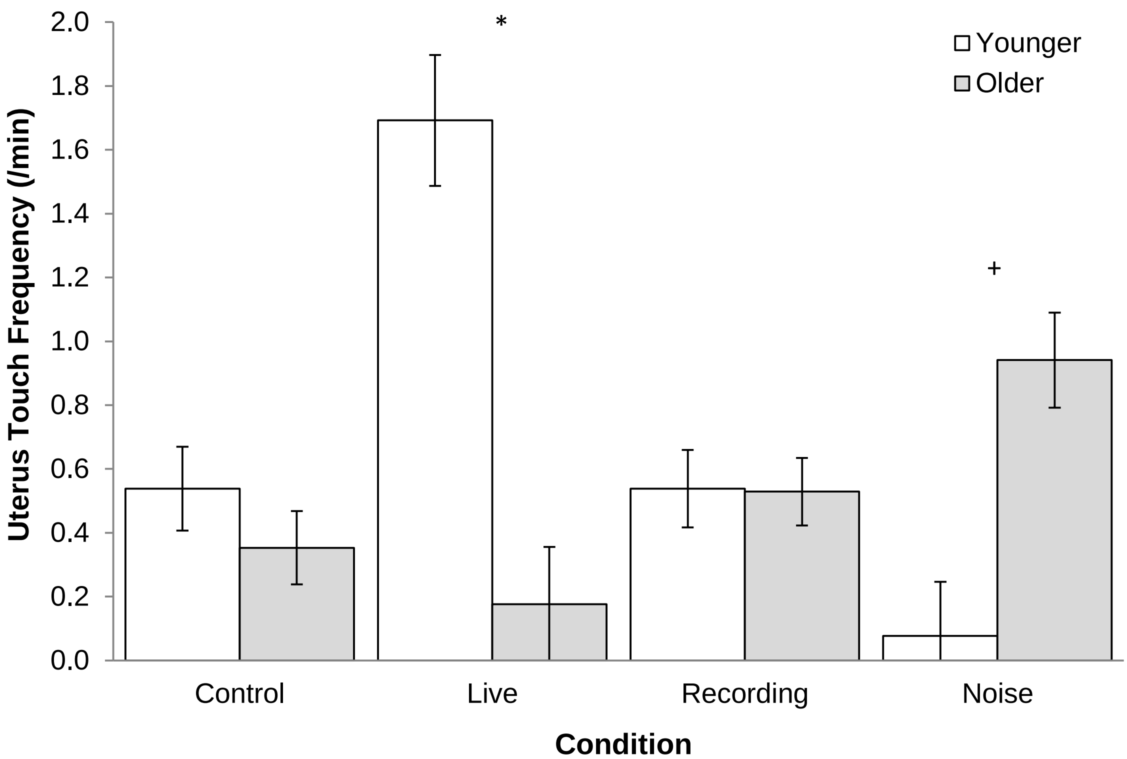

Figure 2.67. Average 'Uterus touch' frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

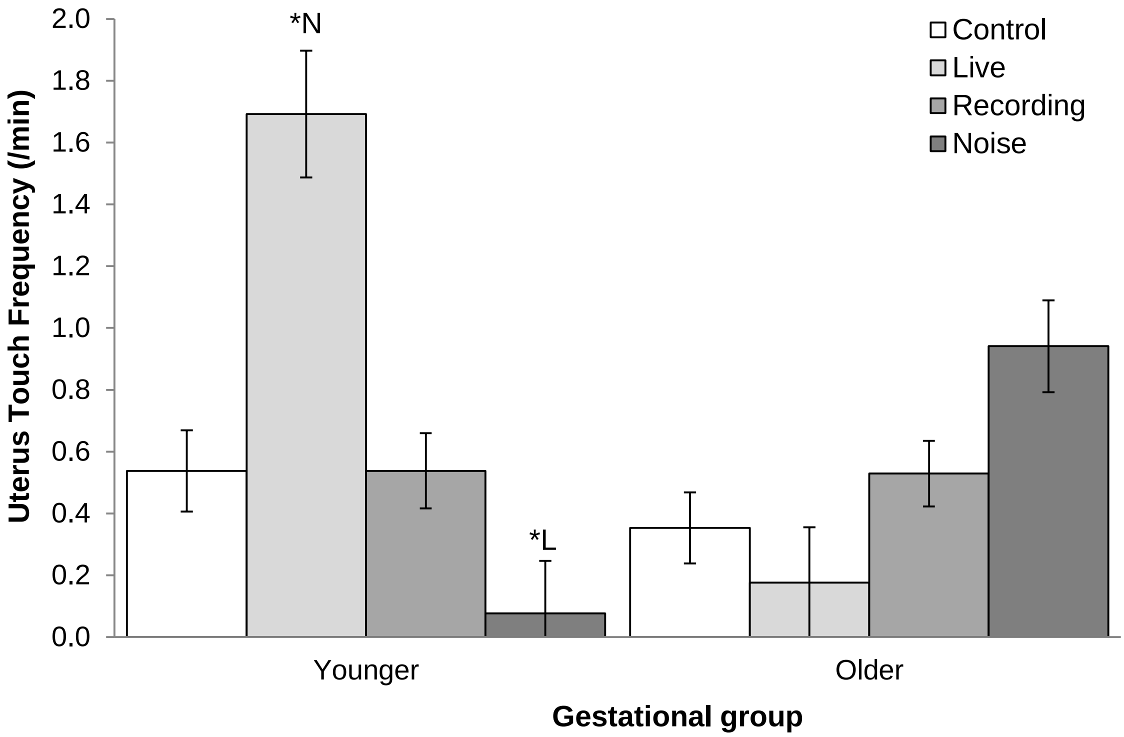

Figure 2.68. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Uterus Touch’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘Uterus touch’ duration and GA across the four Conditions (Control, Live, Recording, Noise). A significant interaction between Condition and GA, F (3, 84) = 3.29, p = .025, η_p^2 = .11 was found. No main effects of Condition F (3, 84) = 1.65, p = .184, η_p^2 = .06, or GA F (1, 28) = 1.57, p = .221, η_p^2 = .05, were found. In support of this polynomial contrasts of the interaction indicated a significant linear trend F (1, 28) = 7.63, p = .010, η_p^2 = .21.

Post-hoc analysis of the interaction showed that younger fetuses (M = 42.36) touch the uterus significantly longer in ‘Live’ compared to older fetuses (M = 9.88, p = .016). A further tendency was observed between age groups in ‘Noise’, with older fetuses (M = 20.53) touching longer compared to younger fetuses (M = 3.11, p = .094). Younger fetuses touched the uterus significantly longer in ‘Live’ (M = 42.36) compared to ‘Noise’ (M = 3.11, p = .015) (see

Figures 2.69 and 2.70). No further effects were found. The means and standard errors can be examined in Table 2.40.

Table 2.40. Means and standard errors (SE) of fetuses ‘Uterus touch’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	24.07	5.74	14.53	5.02		
Control	21.82	9.08	6.58	7.94	14.20	6.03
Live	42.36	9.52	9.88	8.33	26.12	6.33
Recording	28.98	11.11	21.13	9.71	25.06	7.38
Noise	3.11	7.57	20.53	6.62	11.82	5.03

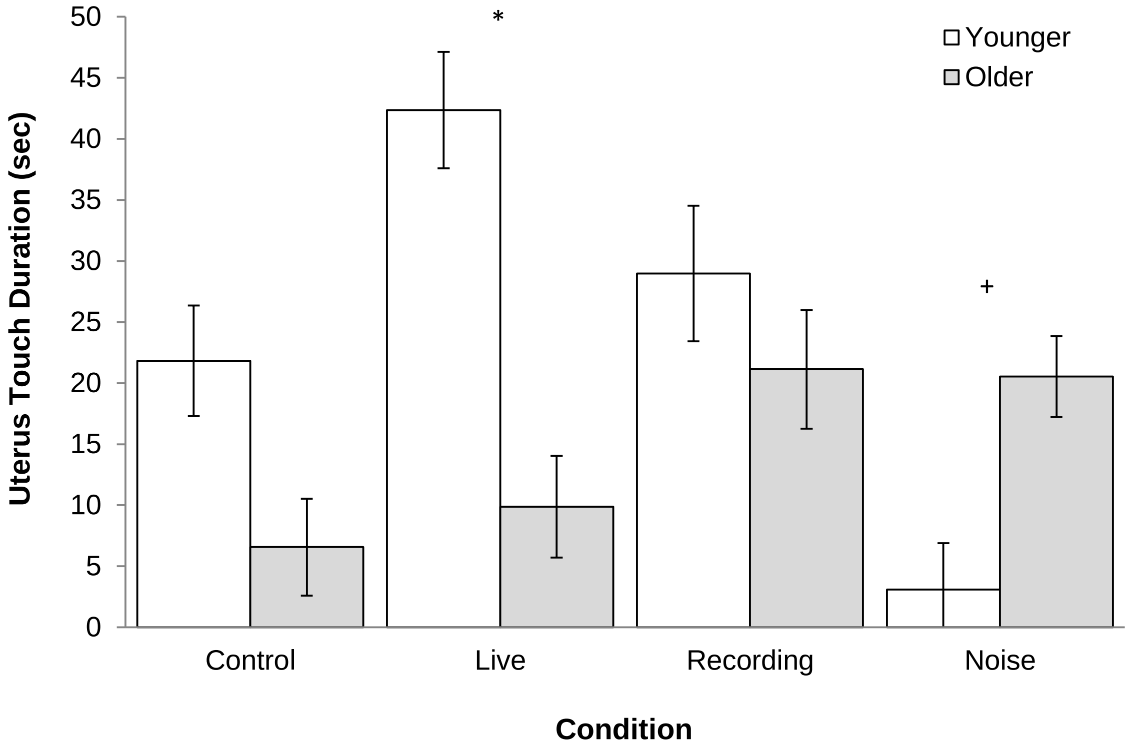

Figure 2.69. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

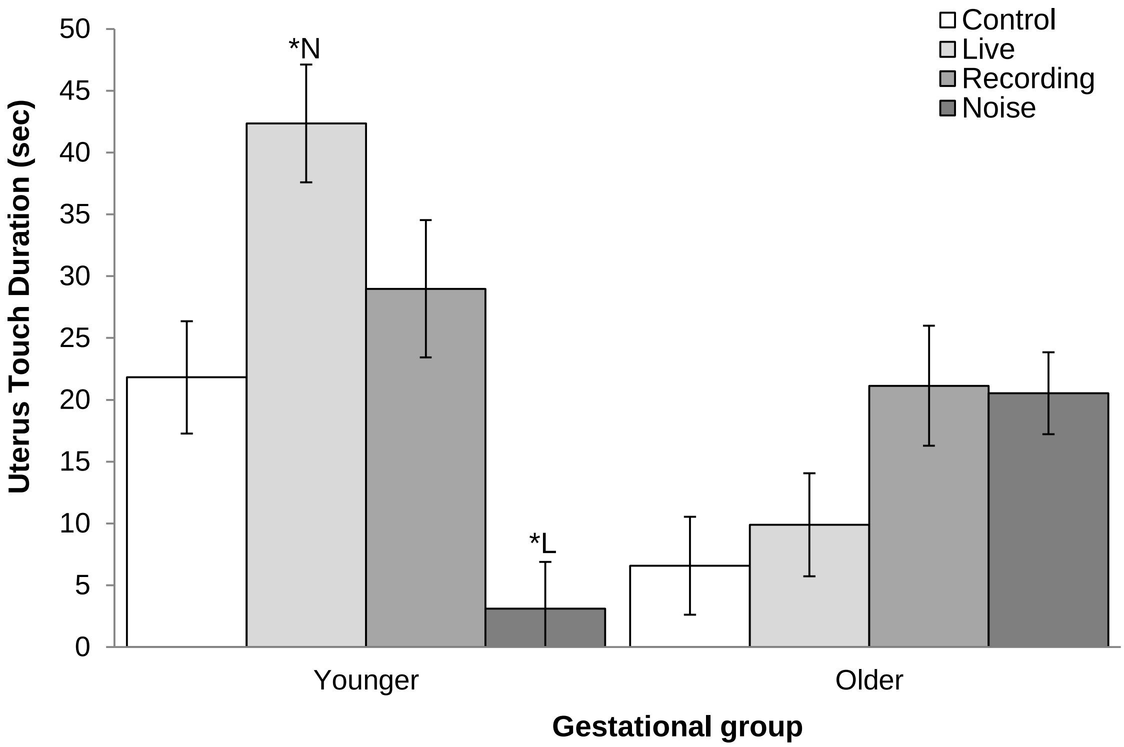

Figure 2.70. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Sucking’ Frequency*

A mixed design ANOVA, using Greenhouse-Geisser correction, was conducted to assess differences in ‘Sucking’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a tendency for GA, F (1, 28) = 3.46, p = .074, η_p^2 = .11. Findings indicated that ‘Sucking’ frequency tends to differ between younger and older fetuses. No main effects of Condition F (1.49, 41.69) = 0.68, p = .472, η_p^2 = .02, or an interaction F (1.49, 41.69) = 0.68, p = .472, η_p^2 = .02, were found.

In support of this post-hoc analysis of the GA main effect showed that younger fetuses (M = 0.00) tended to suck less than older fetuses (M = 0.18; p = .074) (see Figure 2.71). No further effects were found. The means and standard errors can be examined in Table 2.69.

Table 2.41. Means and standard errors (SE) on the frequency of fetuses sucking rate of across conditions.

	Gestational Age	
	Younger Fetuses (<26 weeks)	Older fetuses (=>27 weeks)
Mean	0.00	0.10
SE	0.04	0.04

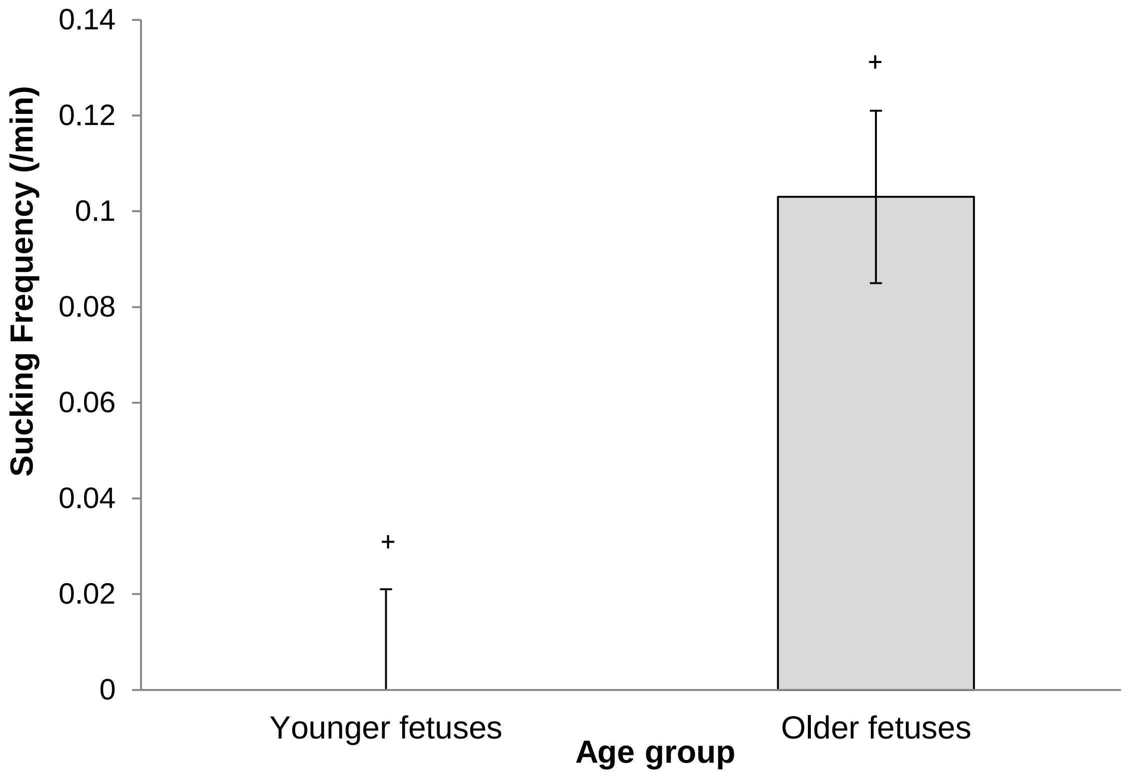

Figure 2.71. Average 'Sucking' frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Face press' Frequency*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences in 'Face press' frequency and GA across the four Conditions (Control, Live, Recording, Noise). The Condition main effect indicates a trend, F (2.59, 72.41) = 2.76, p = .056, η_p^2 = .09. No main effects of GA F (1, 28) = 0.09, p = .767, η_p^2 < .001, or an interaction F (2.59, 72.41) = 1.40, p = .252, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 28) = 7.52, p = .011, η_p^2 = .21, of Condition. Overall, there is a tendency for a linear increase produced by the means from ‘Control’ (M = 0.21) to the ‘Noise’ condition (M = 0.47). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.22) than the ‘Live’ condition (M = 0.32) producing the significant cubic trend.

Post-hoc analysis of the Condition main effect showed a tendency between ‘Control’ and ‘Noise’ with a higher ‘Face press’ frequency in ‘Noise’ (M = 0.47) compared to ‘Control’ (M = 0.21, p = .080) (see Figure 2.72). No further effects were found. The means and standard errors can be examined in Table 2.42.

Table 2.42. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.29	0.09	0.32	0.08		
Control	0.31	0.11	0.12	0.10	0.21	0.07
Live	0.12	0.13	0.41	0.12	0.32	0.09
Recording	0.15	0.12	0.29	0.11	0.22	0.08
Noise	0.46	0.14	0.47	0.13	0.47	0.10

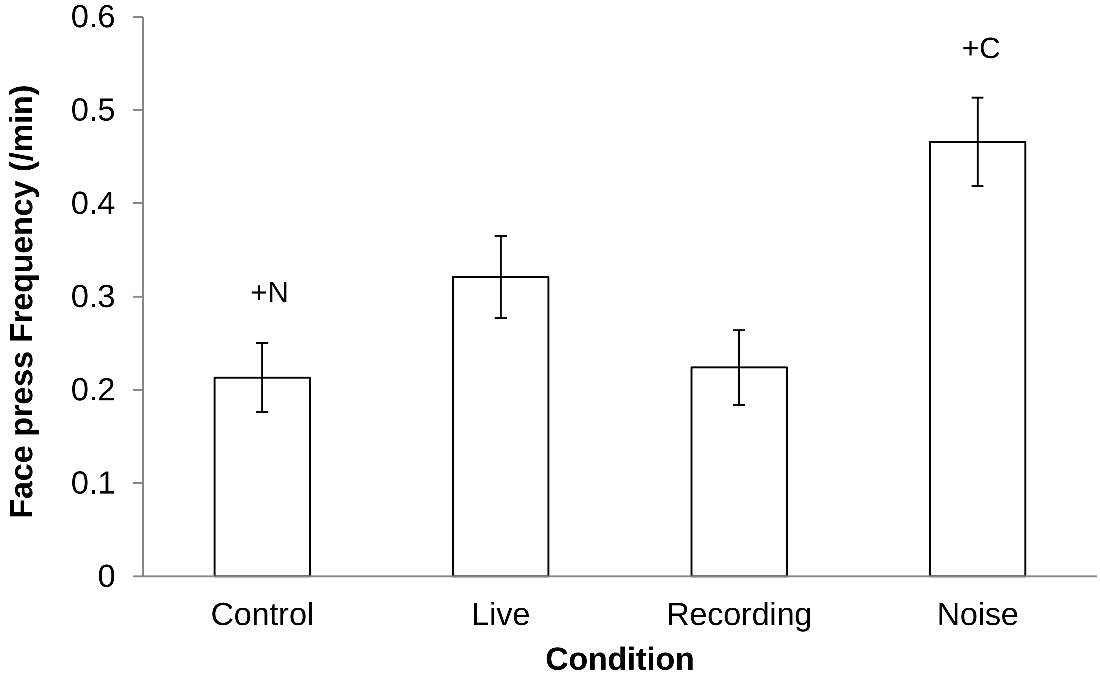

Figure 2.72. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘Face press’ duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results show a significant main effect of Condition F (2.55, 71.26) = 2.95, p = .047, η_p^2 = .10. No main effects of GA F (1, 28) = 0.13, p = .720, η_p^2 = .01, or an interaction F (2.55, 71.26) = 1.41, p = .250, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 4.42, p = .045, η_p^2 = .14, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 28) = 7.79, p = .009, η_p^2 = .22. Overall, there is a linear increase produced by the means from ‘Control’ (M = 20.52) to the ‘Noise’ condition (M = 46.61). However, the ‘Recording’ condition has a somewhat lower mean (M = 22.40) than the ‘Live’ condition (M = 31.42) producing the cubic trend.

Post-hoc analysis of the main effect of condition showed a tendency between ‘Control’ and ‘Noise’ with a longer duration of ‘Face press’ in ‘Noise’ (M = 46.61)

compared to ‘Control’ (M = 20.52, p = .065) (see Figure 2.73). No further effects were found. The means and standard errors can be examined in Table 2.43.

Table 2.43. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	28.12	8.79	32.35	7.69		
Control	29.28	10.87	11.77	9.51	20.52	7.22
Live	21.66	13.02	41.18	11.39	31.42	8.65
Recording	15.39	11.98	29.41	10.47	22.40	7.96
Noise	46.15	14.32	47.06	12.52	46.61	9.51

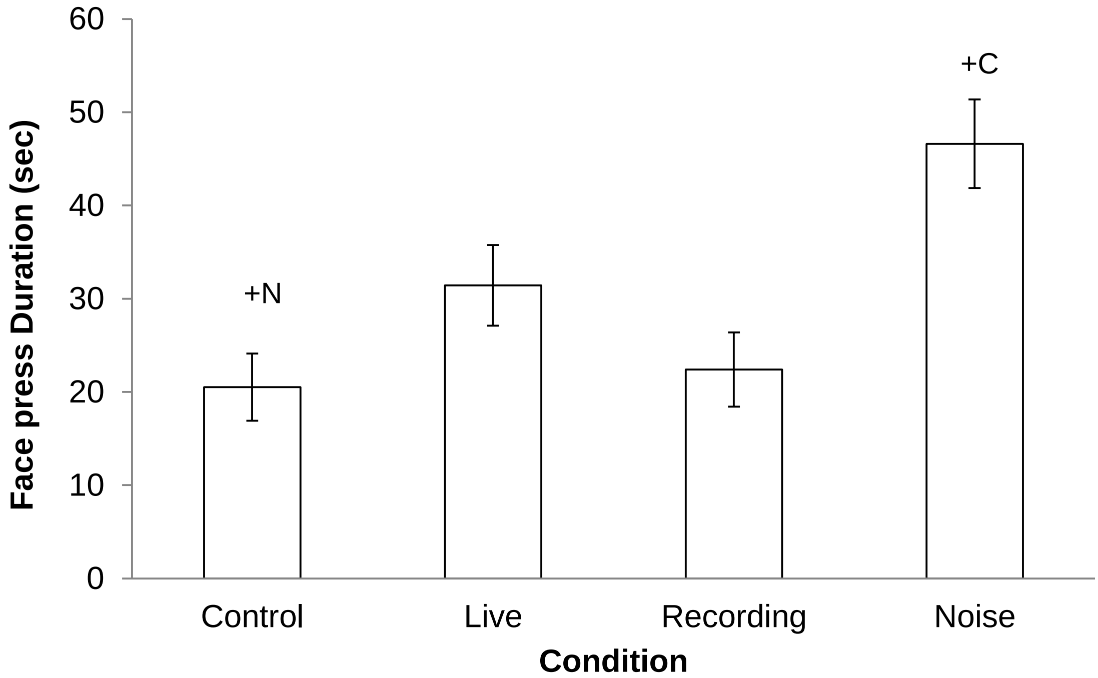

Figure 2.73. Average ‘Face press’ duration (per minute) including standard errors for each condition (.05 ≥+≤ .10).

0-60 Interval analysis combined

*Mixed-design ANOVA Condition*GA: ‘Self-touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Self-touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results showed no significant main effects of Condition F (3, 84) = 0.19, p = .905, η_p^2 = .01, and GA F (1, 28) = 0.15, p = .702, η_p^2 = .01. However, a marginally significant interaction between Condition and GA, F (3, 84) = 2.64, p = .055, η_p^2 = .09, was found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 28) = 5.01, p = .033, η_p^2 = .15.

Post-hoc analysis of the interaction did not reveal any further effects (see Figures 2.74 and 2.75). No further effects were found. The means and standard errors can be examined in Table 2.44.

Table 2.44. Means and standard errors (SE) of fetuses ‘Self-touch’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.67	0.34	1.50	0.30		
Control	1.39	0.48	1.29	0.42	1.34	0.32
Live	2.15	0.47	1.12	0.41	1.64	0.31
Recording	2.23	0.53	1.00	0.46	1.62	0.35
Noise	0.92	0.92	2.59	0.81	1.76	0.61

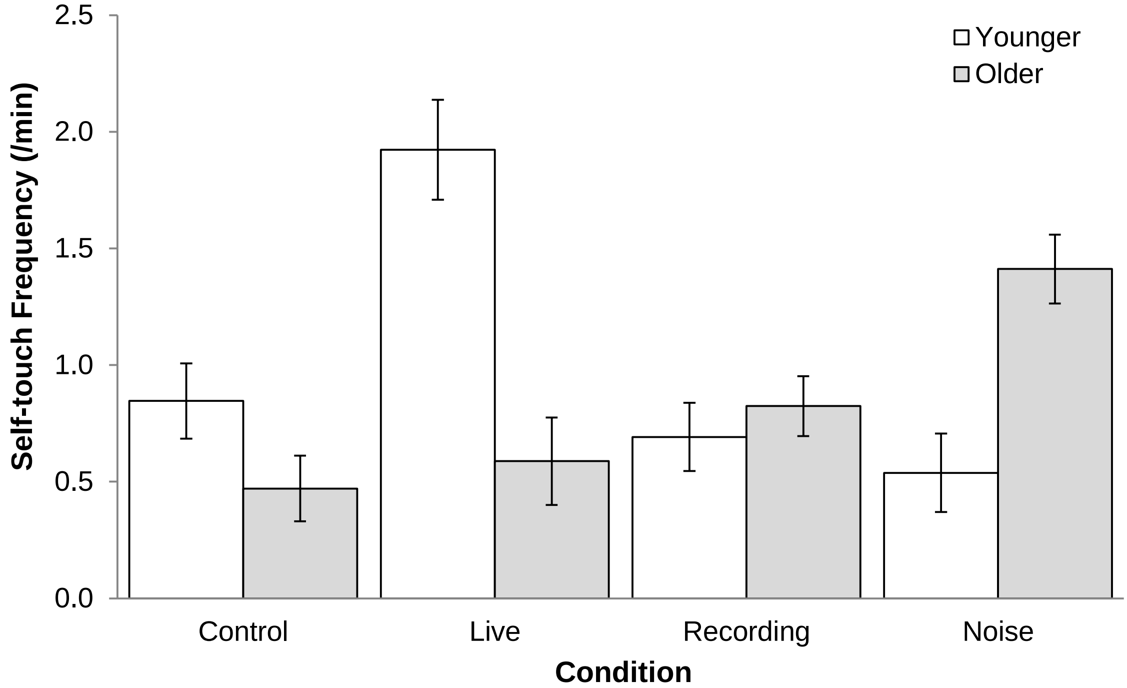

Figure 2.74. Average 'Self-touch' frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses).

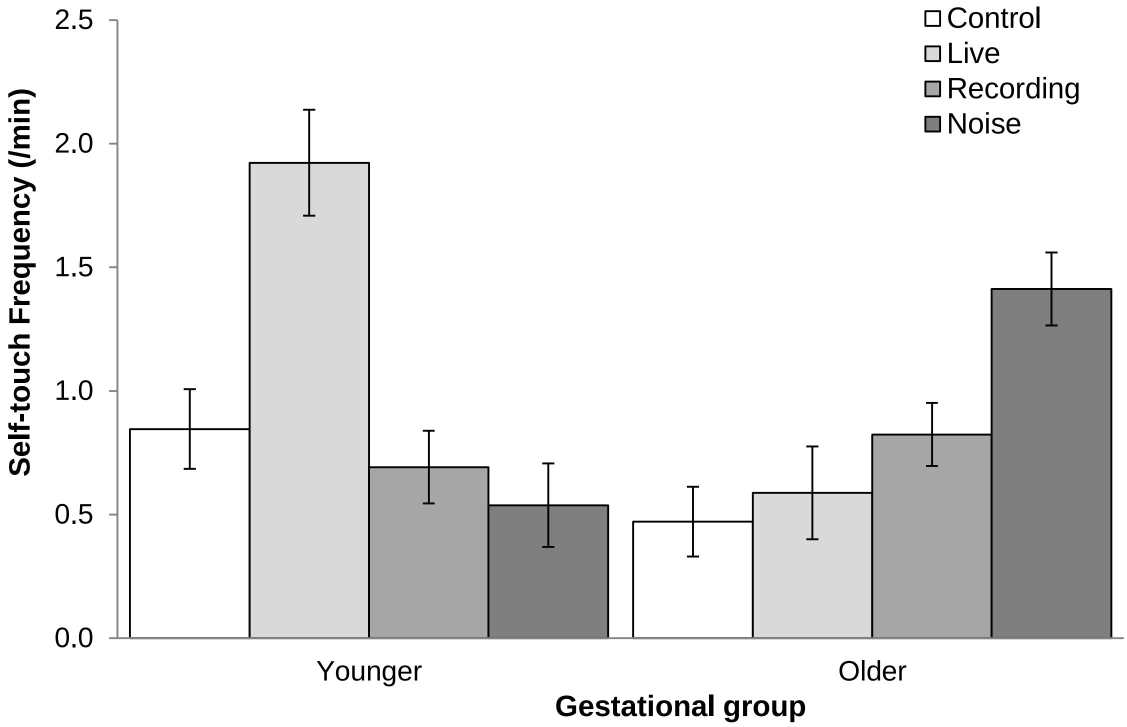

Figure 2.75. Average 'Self-touch' frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: ‘External Touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘External touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results showed no significant main effects of Condition F (3, 84) = 1.31, p = .276, η_p^2 = .05, and GA F (1, 28) = 0.57, p = .458, η_p^2 = .02. However, a significant interaction between Condition and GA, F (3, 84) = 4.02, p = .010, η_p^2 = .13, was found. In support of this polynomial contrasts indicated a significant linear trend of Condition and GA F (1, 28) = 10.07, p = .008, η_p^2 = .22. Post-hoc analysis of the interaction showed a significant difference in ‘Live’, with younger fetuses (M = 1.92) increasing ‘External touch’ frequency compared to older fetuses (M = 0.59, p = .027). A marginally significant difference was revealed in ‘Noise’, with older fetuses (M = 1.41) displaying more ‘External touch’ compared to younger fetuses (M = 0.54, p = .061) (see Figures 2.76 and 2.77. No further effects were found. The means and standard errors can be examined in Table 2.45.

Table 2.45. Means and standard errors (SE) of fetuses ‘External touch’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.00	0.18	0.82	0.15		
Control	0.85	0.32	0.47	0.28	0.66	0.21
Live	1.92	0.43	0.59	0.38	1.26	0.29
Recording	0.69	0.29	0.82	0.26	0.76	0.20
Noise	0.54	0.34	1.41	0.30	0.98	0.22

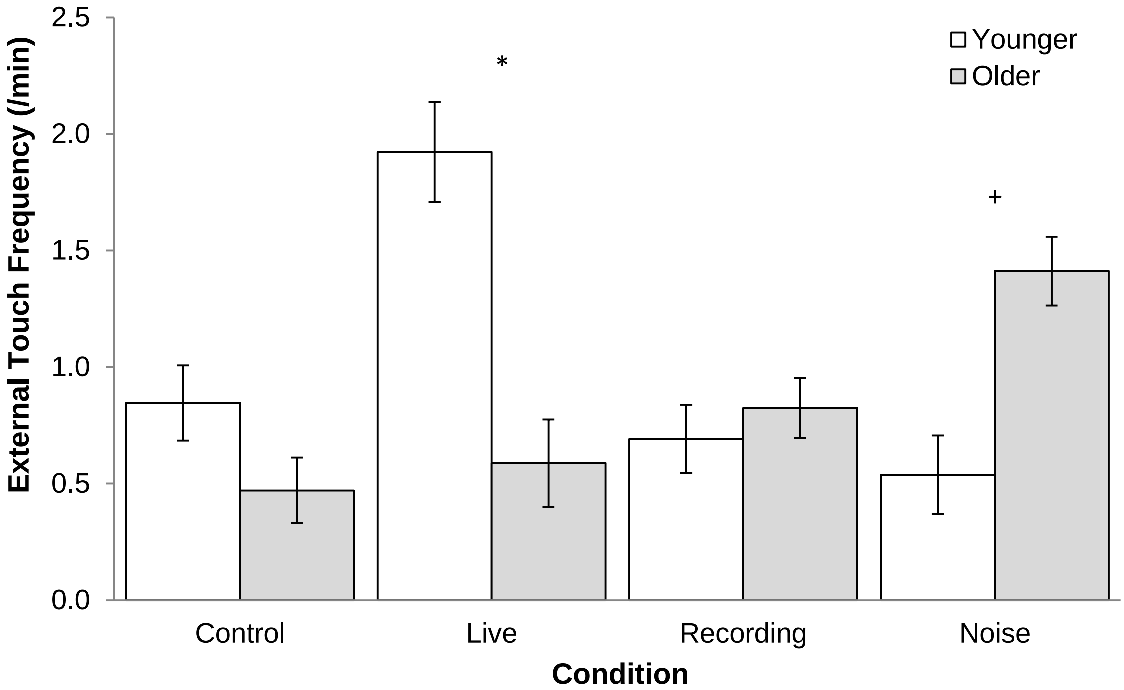

Figure 2.76. Average ‘External touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

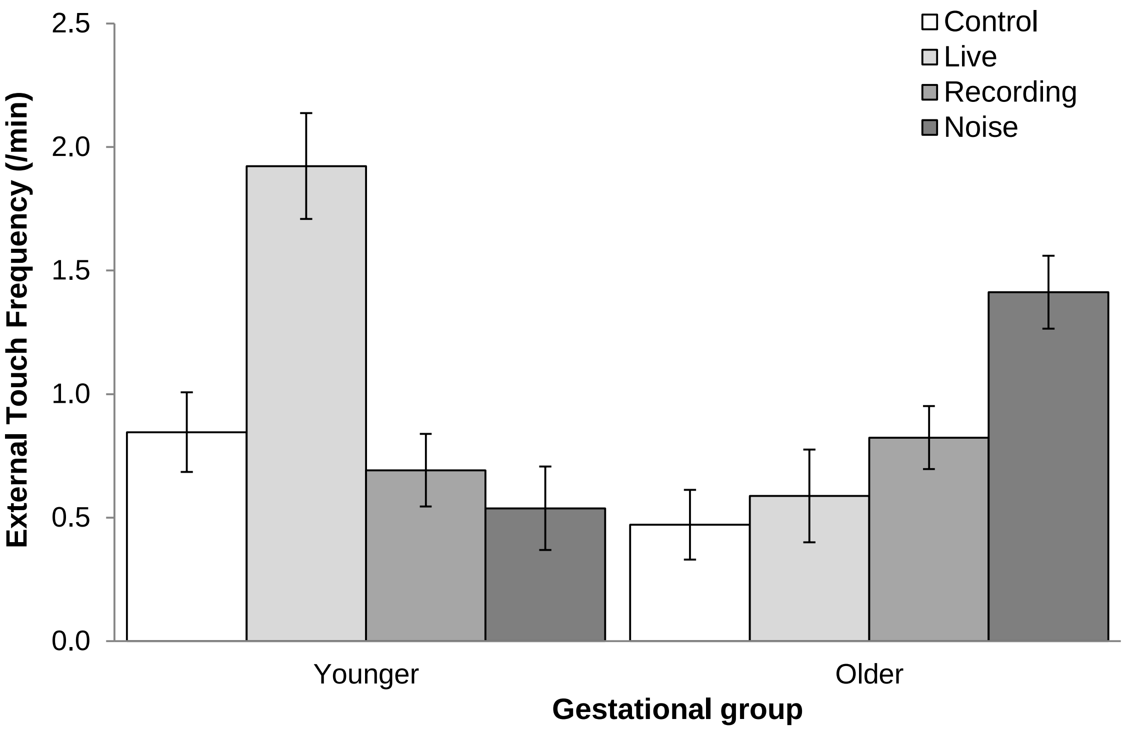

Figure 2.77. Average ‘External touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses).

30-60 Interval analysis

Repeated-measures ANOVA Condition: ‘Face press’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). As the assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results indicate that there was a trend in ‘Face press’ frequency between the four Conditions F (2.53, 73.40) = 2.89, p = .050, η_p^2 = .09.

Examination of these means suggests that fetuses ‘Face press’ frequency changed depending on Condition. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 4.62, p = .040, η_p^2 = .14. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.37, p = .007, η_p^2 = .22. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.40) to the ‘Noise’ condition (M = 0.93). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.47) than the ‘Live’ condition (M = 0.67) producing the cubic trend.

Post-hoc analysis showed a trend between ‘Noise’ and ‘Control’, with increased ‘Face press’ in the ‘Noise’ (M = 0.93) condition compared to ‘Control’ (M = 0.40, p = .053) (see Figure 2.78). No further effects were found. The means and standard errors can be examined in Table 2.46.

Table 2.46. Means and standard errors (SE) on the frequency of fetuses ‘Face press’ of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	0.40	0.67	0.47	0.93
SE	0.15	0.18	0.16	0.19

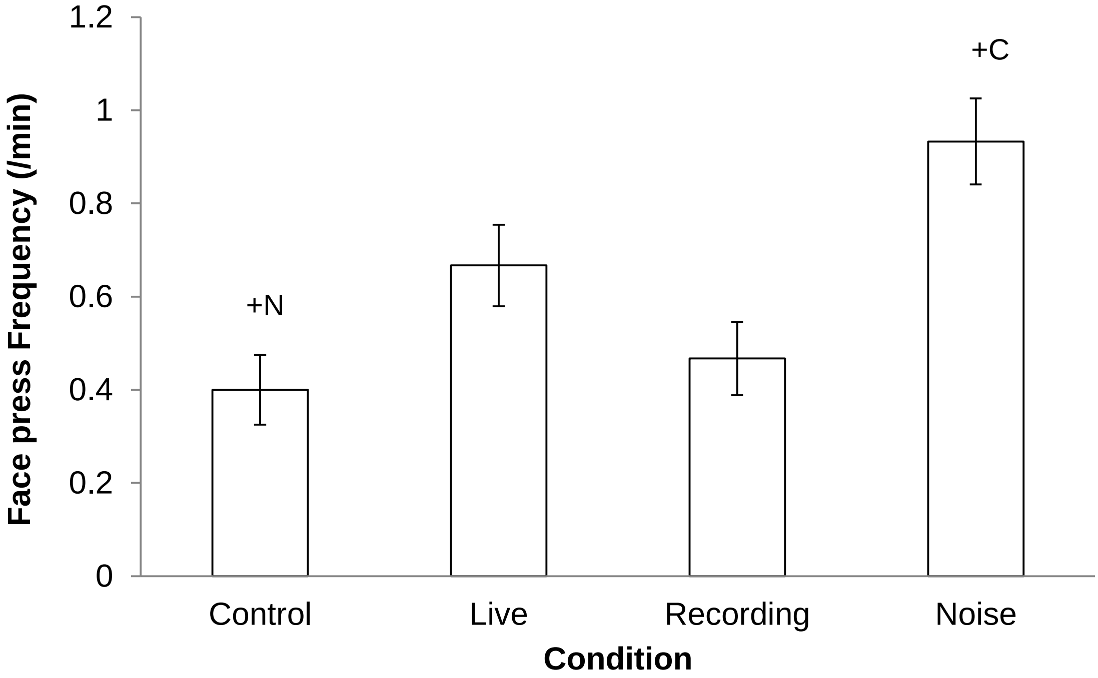

Figure 2.78. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in duration of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). Results indicate that there was a significant difference in ‘Face press’ duration between the four Conditions F (2.5, 72.51) = 3.18, p = .037, η_p^2 = .10. Examination of these means suggests that the duration of fetuses touching the uterine wall with their face differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.16, p = .031, η_p^2 = .15. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.84, p = .006, η_p^2 = .23. Overall, there is a linear increase produced by the means from ‘Control’ (M = 18.71) to the ‘Noise’ condition (M = 46.67). However, the ‘Recording’ condition has a somewhat lower mean (M = 23.33) than the ‘Live’ condition (M = 33.33) producing the cubic trend.

Post-hoc analysis showed a significant difference between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ duration in the ‘Noise’ (M = 46.67) condition compared to 'Control' (M = 18.71, p = .037) (see Figure 2.79). No further effects were found. The means and standard errors can be examined in Table 2.47.

Table 2.47. Means and standard errors (SE) on the duration of fetuses facial touch of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	18.71	33.33	23.33	46.67
SE	7.05	8.75	7.85	9.26

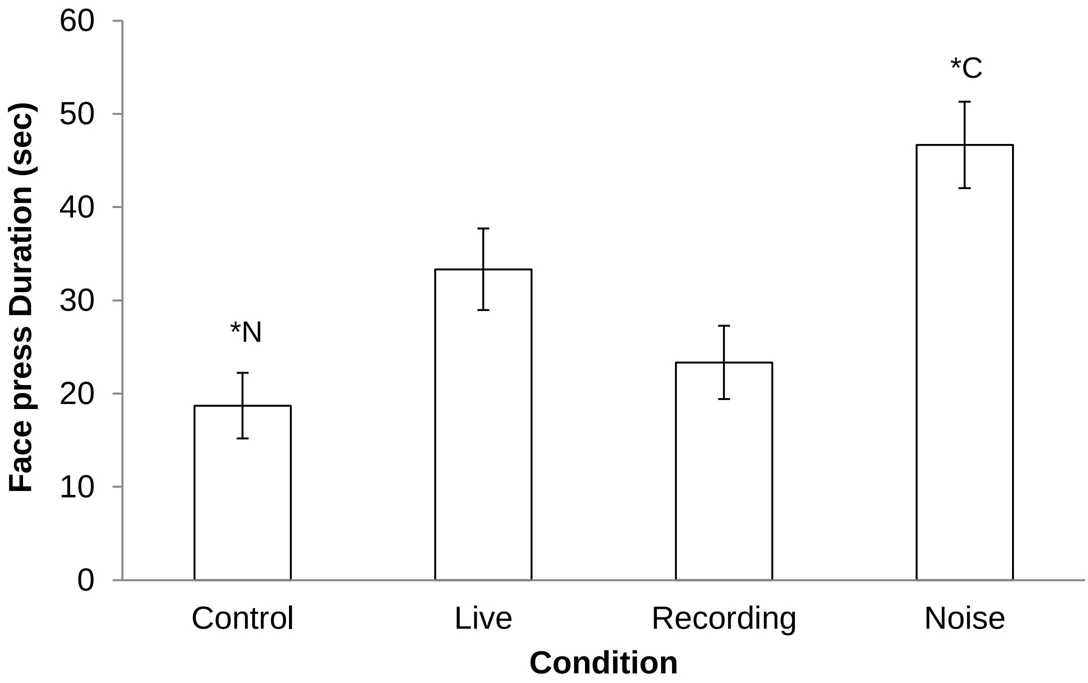

Figure 2.79. Average 'Face press' duration (in seconds) including standard errors for each condition (*< .05).

*Mixed-design ANOVA Condition*GA: 'Body Touch' Frequency*

A mixed design ANOVA was conducted to assess differences in 'Body touch' frequency and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. Results showed a significant interaction between Condition and GA, F (2.04, 57.17) = 3.16, p = .049, η_p^2 = .10. No main effects of Condition F (2.04, 57.17) = 0.65 p = .529, η_p^2 = .02, or GA F (1, 28) = 0.31, p = .583, η_p^2 = .01, were found. In support of this polynomial contrasts of the interaction indicated a significant cubic trend F (1, 28) = 4.74, p = .038, η_p^2 = .15. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.53, p = .007, η_p^2 = .23. Post-hoc analysis of the interaction showed a tendency in 'Control' for older (M = 0.12) fetuses increasing 'Body touch' frequency compared to younger fetuses (M = 0.92, p = .080). Likewise, an increased tendency of 'Body touch' in the 'Noise' condition for older (M = 1.65) compared to younger fetuses (M = 0.15, p = .074) was observed (see Figures 2.80 and 2.81). No further effects were found. The means and standard errors can be examined in Table 2.48.

Table 2.48. Means and standard errors (SE) of fetuses 'Body touch' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.54	0.23	0.71	0.20		
Control	0.92	0.33	0.12	0.29	0.52	0.22
Live	0.31	0.27	0.47	0.24	0.39	0.18
Recording	0.77	0.40	0.59	0.35	0.68	0.27
Noise	0.15	0.61	1.65	0.53	0.90	0.40

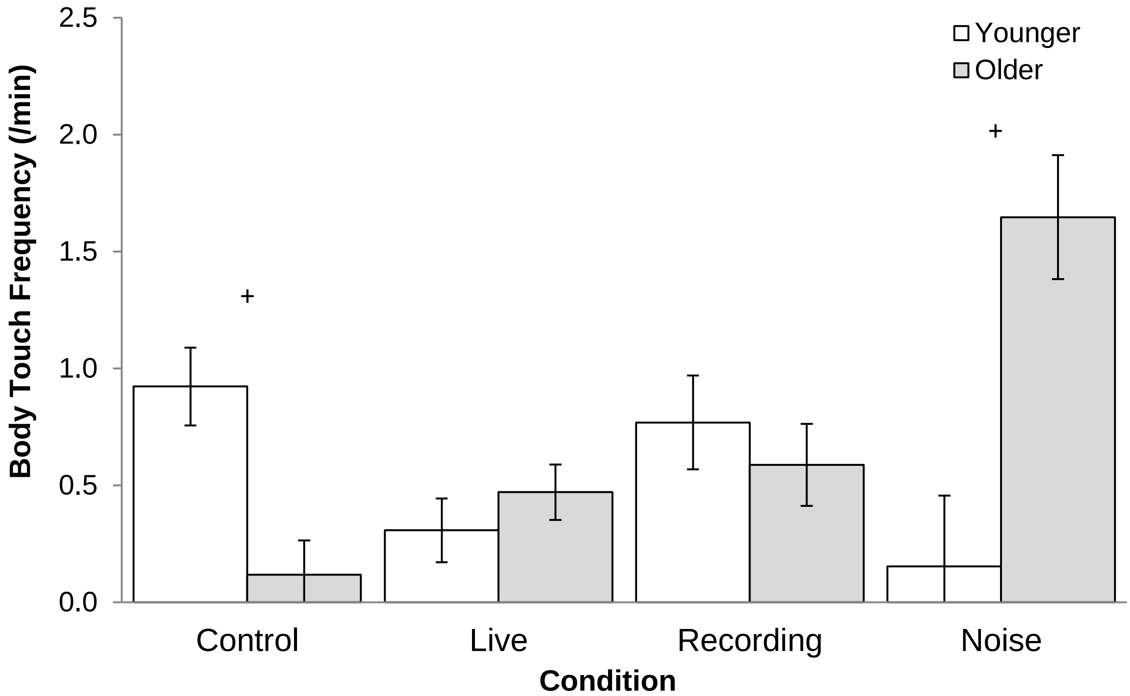

Figure 2.80. Average ‘Body touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10).

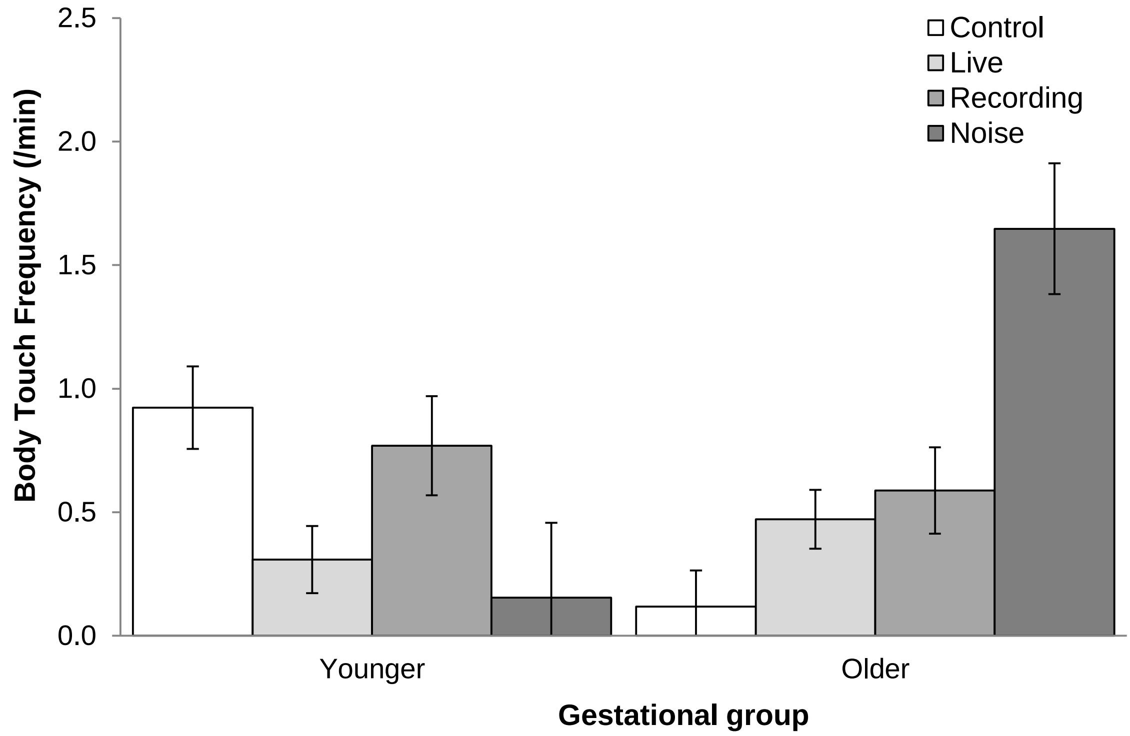

Figure 2.81. Average ‘Body touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: 'Uterus Touch' Frequency*

A mixed design ANOVA was conducted to assess differences in 'Uterus touch' frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a significant interaction between Condition and GA, F (3, 84) = 4.81, p = .004, η_p^2 = .15. No main effects of Condition F (3, 84) = 0.95 p = .423, η_p^2 = .03, or GA F (1, 28) = 0.42, p = .522, η_p^2 = .02, were found. Findings indicated that 'Uterus touch' frequency is dependent on Condition and GA. In support of this, polynomial contrasts of the interaction indicated a significant linear trend F (1, 28) = 5.27, p = .029, η_p^2 = .16. This finding is qualified by the significant quadratic trend of Condition and GA F (1, 28) = 4.84, p = .036, η_p^2 = .15

Post-hoc analysis of the interaction showed that younger fetuses (M = 2.46) touched the uterus significantly more in 'Live' compared to older fetuses (M = 0.35, p = .007). In the 'Noise' condition older fetuses (M = 1.53) tended to touch the uterus more than younger fetuses (M = 0.15, p = .092). Younger fetuses significantly increased 'Uterus touch' frequency in 'Live' (M = 2.46, p = .020) and 'Recording' (M = 0.62, p = .049) compared to 'Noise' (M = 0.15) (see Figures 2.82 and 2.83). No further effects were found. The means and standard errors can be examined in Table 2.49.

Table 2.49. Means and standard errors (SE) of fetuses 'Uterus touch' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.04	0.25	0.82	0.22		
Control	0.92	0.48	0.59	0.42	0.76	0.32
Live	2.46	0.54	0.35	0.47	1.41	0.36
Recording	0.62	0.35	0.82	0.30	0.72	0.23
Noise	0.15	0.59	1.53	0.51	0.84	0.39

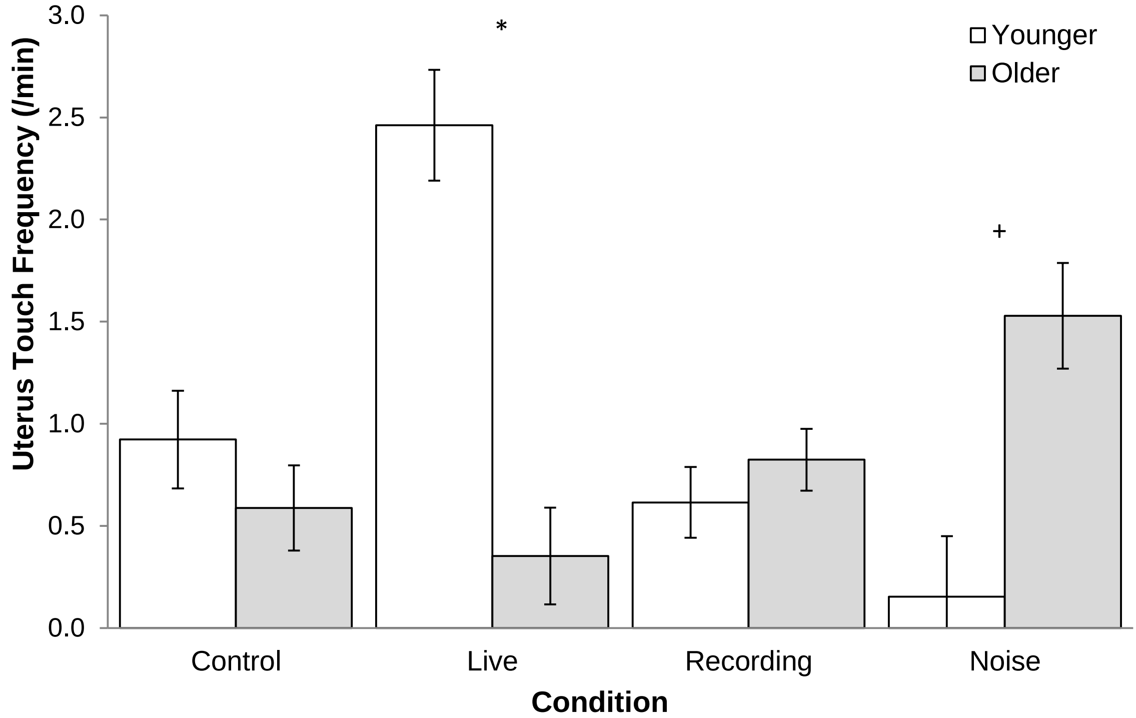

Figure 2.82. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

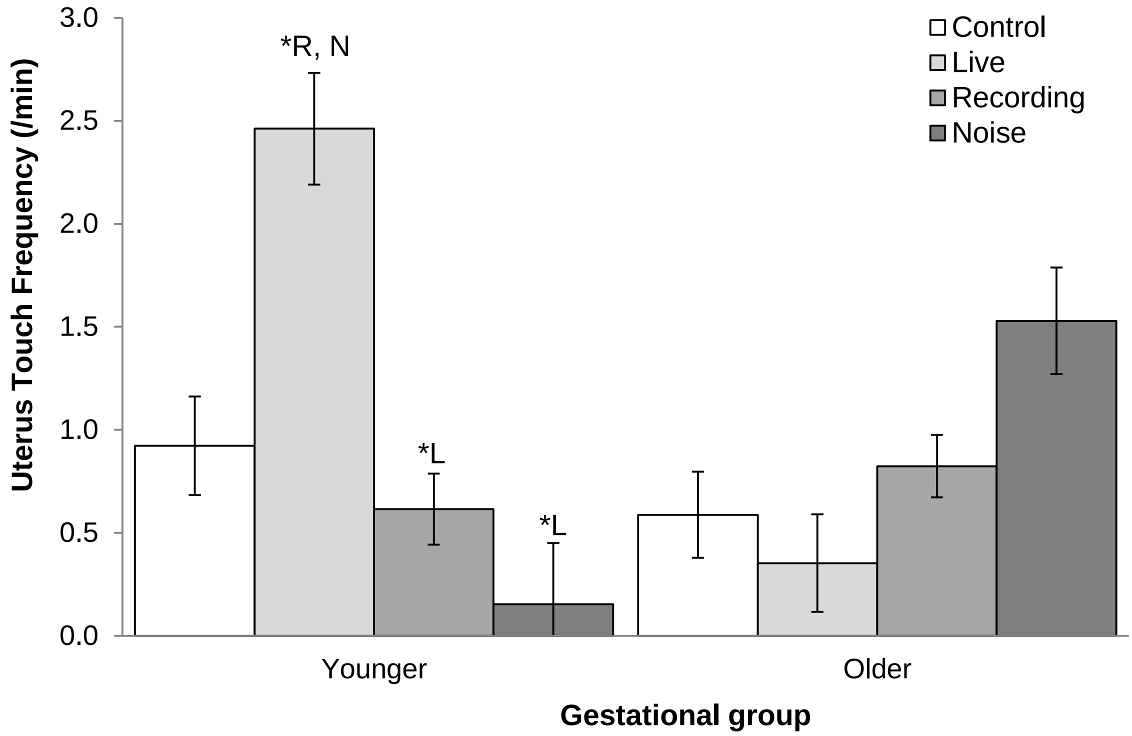

Figure 2.83. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: 'Uterus Touch' Duration*

A mixed design ANOVA was conducted to assess differences in 'Uterus touch' duration and GA across the four Conditions (Control, Live, Recording, Noise). The interaction between Condition and GA showed a tendency, F (3, 84) = 2.18, p = .096, η_p^2 = .07. No main effects of Condition F (3, 84) = 1.63 p = .190, η_p^2 = .06, or GA F (1, 28) = 1.56, p = .223, η_p^2 = .05, were found. In support of this polynomial contrasts of the interaction indicated a significant linear trend F (1, 28) = 5.50, p = .026, η_p^2 = .16.

Post-hoc analysis of the interaction showed that younger fetuses (M = 43.62) touch the uterus significantly longer in 'Live' compared to older fetuses (M = 13.89, p = .037). Younger fetuses displayed significantly longer 'Uterus touch' durations in 'Live' (M = 43.62) compared to 'Noise' (M = 6.21, p = .038) (see Figures 2.84 and 2.85). No further effects were found. The means and standard errors can be examined in Table 2.50.

Table 2.50. Means and standard errors (SE) of fetuses 'Uterus touch' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	24.62	5.75	15.08	5.03		
Control	21.64	9.06	7.19	7.92	14.41	6.02
Live	43.62	10.20	13.89	8.92	28.76	6.77
Recording	27.00	11.05	20.22	9.66	23.61	7.34
Noise	6.21	8.29	19.04	7.25	12.63	5.51

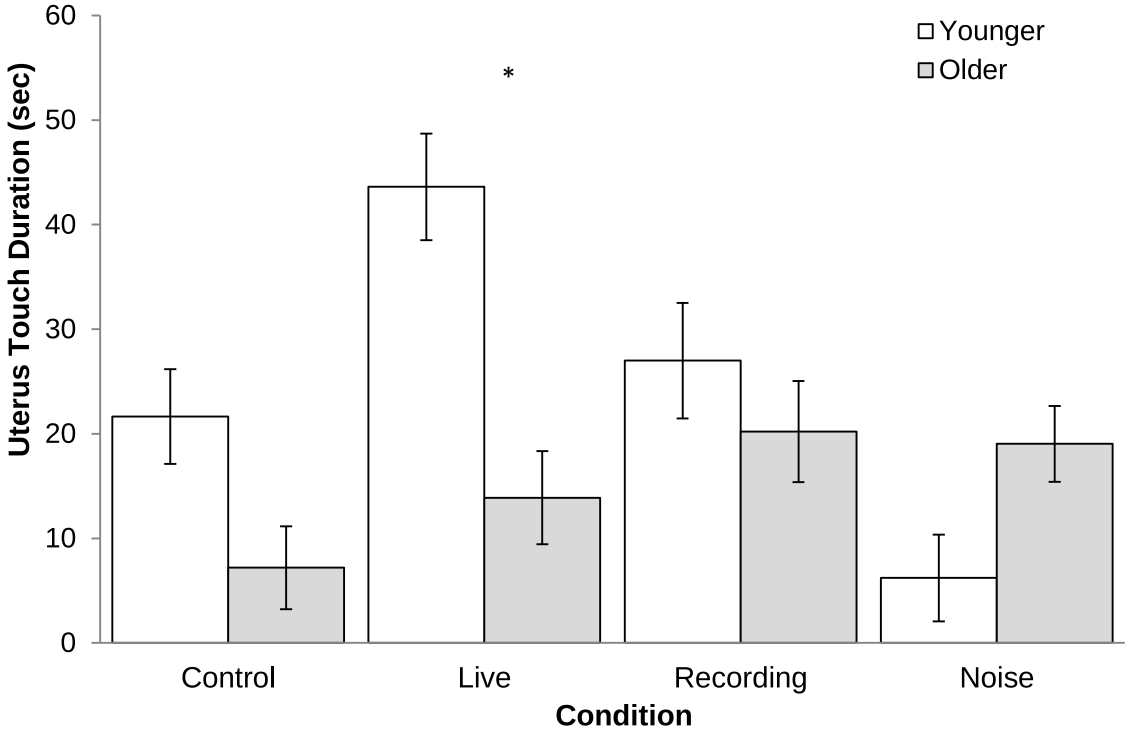

Figure 2.84. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (*< .05).

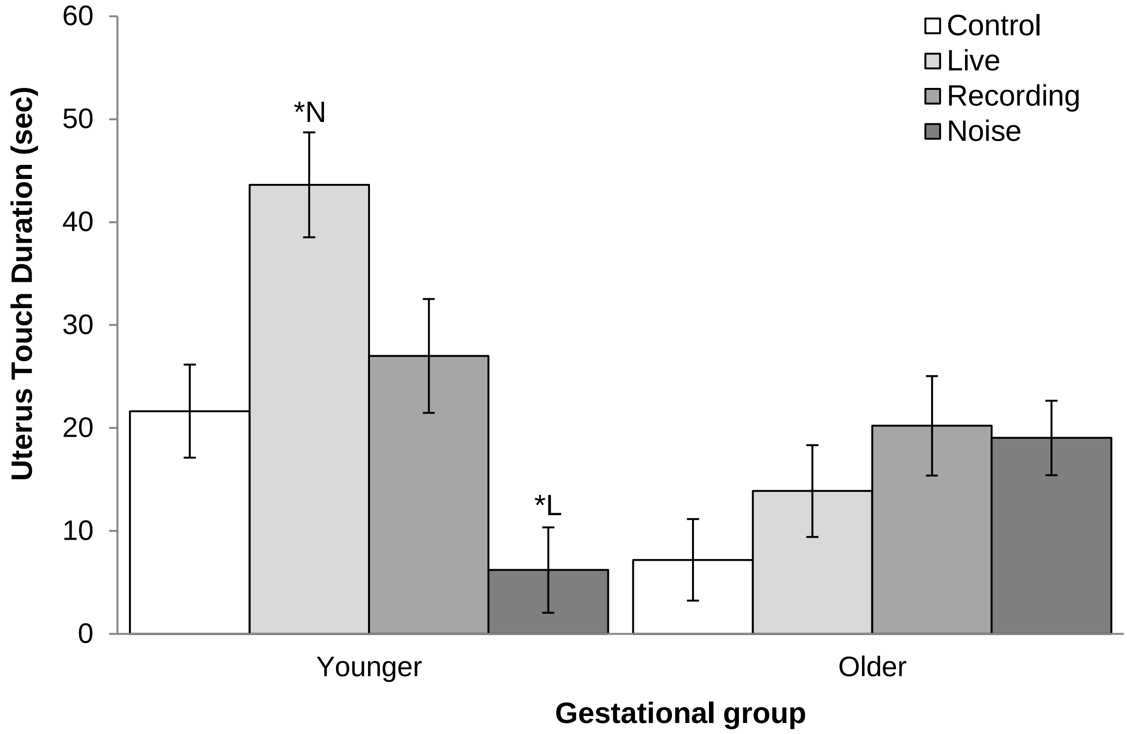

Figure 2.85. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: 'Face press' Frequency*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences in 'Face press' frequency and GA across the four Conditions (Control, Live, Recording, Noise). The Condition main effect indicates a trend, F (2.59, 72.41) = 2.76, p = .056, η_p^2 = .09. No main effects of GA F (1, 28) = 0.09, p = .767, η_p^2 < .001, or an interaction F (2.59, 72.41) = 1.40, p = .252, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 28) = 7.52, p = .011, η_p^2 = .21 of Condition. Overall, there is a slight linear increase produced by the means from 'Control' (M = 0.43) to the 'Noise' condition (M = 0.93). However, the 'Recording' condition has a somewhat lower mean (M = 0.45) than the 'Live' condition (M = 0.63) producing the cubic trend. Post-hoc analysis of the main effect of 'Condition' showed a tendency between 'Control' and 'Noise' with a higher 'Face press' frequency in 'Noise' (M = 0.93) compared to 'Control' (M = 0.43, p = .080) (see Figure 2.86). No further effects were found. The means and standard errors can be examined in Table 2.51.

Table 2.51. Means and standard errors (SE) of fetuses 'Face press' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.58	0.18	0.65	0.15		
Control	0.62	0.22	0.23	0.20	0.43	0.15
Live	0.46	0.27	0.82	0.23	0.64	0.18
Recording	0.31	0.24	0.59	0.21	0.45	0.16
Noise	0.92	0.29	0.94	0.25	0.93	0.19

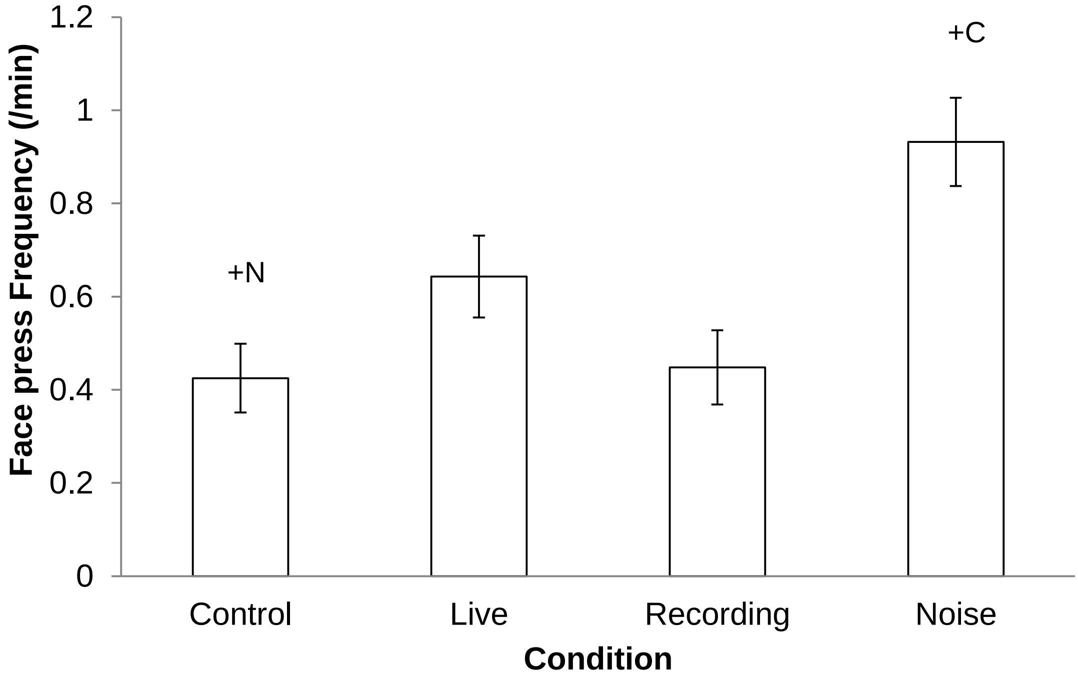

Figure 2.86. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘Face press’ duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results show a significant main effect of Condition F (2.55, 71.43) = 3.02, p = .043, η_p^2 = .10. No main effects of GA F (1, 28) = 0.13 p = .718, η_p^2 = .01, or an interaction F (2.55, 71.43) = 1.21, p = .309, η_p^2 = .04, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 4.57, p = .041, η_p^2 = .14, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 28) = 7.97, p = .009, η_p^2 = .22. Overall, there is a linear increase produced by the means from ‘Control’ (M = 19.78) to the ‘Noise’ condition (M = 46.61). However, the ‘Recording’ condition has a somewhat lower mean (M = 22.40) than the ‘Live’ condition (M = 32.13) producing the cubic trend.

Post-hoc analysis of the main effect of Condition showed a tendency between ‘Control’ and ‘Noise’ with a longer duration of ‘Face press’ in ‘Noise’ (M = 46.61)

compared to ‘Control’ (M = 19.78, *p* = .055) (see Figure 2.87). No further effects were found. The means and standard errors can be examined in Table 2.52.

Table 2.52. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	28.10	8.76	32.35	7.66		
Control	27.80	10.66	11.77	9.32	19.78	7.08
Live	23.08	13.29	41.18	11.62	32.13	8.83
Recording	15.39	11.98	29.41	10.47	22.40	7.96
Noise	46.15	14.32	47.06	12.52	46.61	9.51

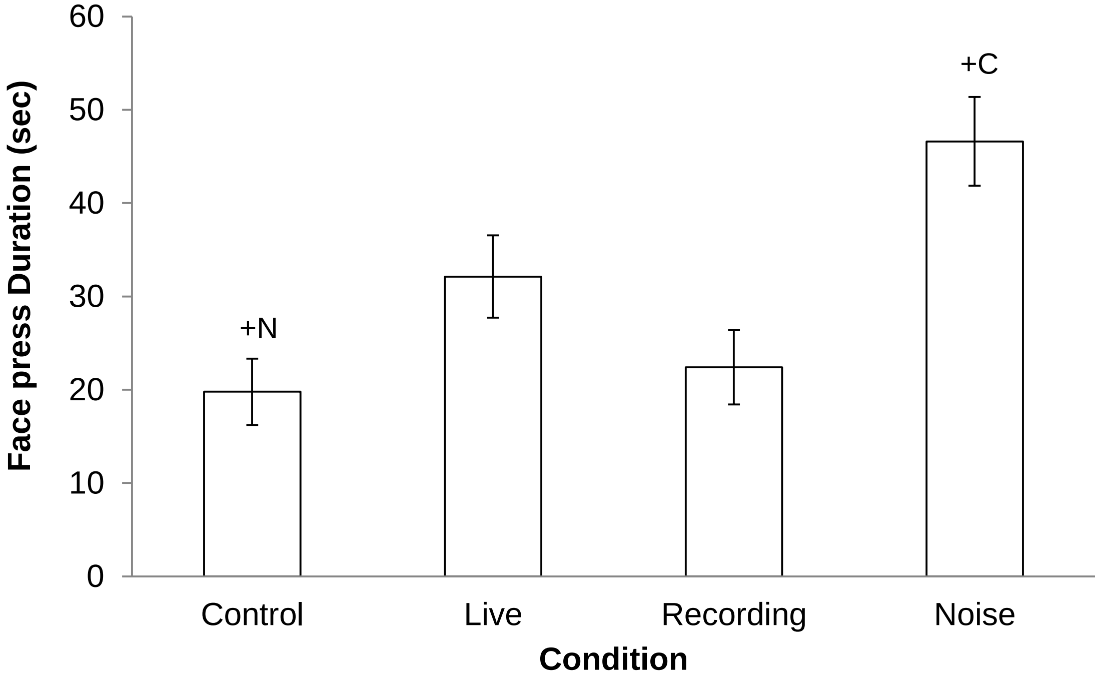

Figure 2.87. Average ‘Face press’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

30-60 Interval analysis combined

*Mixed-design ANOVA Condition*GA: ‘External Touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘External touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results showed no significant main effects of Condition F (3, 84) = 1.41, p = .245, η_p^2 = .05, and GA F (1, 28) = 0.12, p = .731, η_p^2 = .01. However, a significant interaction between Condition and GA, F (3, 84) = 3.43, p = .021, η_p^2 = .11, was found. In support of this polynomial contrasts indicated a significant linear trend of Condition and GA F (1, 28) = 6.48, p = .017, η_p^2 = .19. Post-hoc analysis of the interaction showed a significant difference in ‘Live’, with younger fetuses (M = 2.92) increasing ‘External touch’ frequency compared to older fetuses (M = 1.18, p = .038). A marginally significant difference was revealed in ‘Noise’, with older fetuses (M = 2.47) displaying more ‘External touch’ compared to younger fetuses (M = 1.08, p = .098). A significant difference was revealed for younger fetuses between ‘Live’ and ‘Recording’, with significantly more ‘External touch’ in ‘Live’ (M = 2.92) compared to ‘Recording’ (M = 0.92, p = .017) (see Figures 2.88 and 2.89). No further effects were found. The means and standard errors can be examined in Table 2.53.

Table 2.53. Means and standard errors (SE) of fetuses ‘External touch’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.62	0.31	1.47	0.27		
Control	1.54	0.60	0.82	0.52	1.18	0.40
Live	2.92	0.61	1.18	0.53	2.05	0.40
Recording	0.92	0.48	1.41	0.42	1.17	0.32
Noise	1.08	0.61	2.47	0.54	1.77	0.41

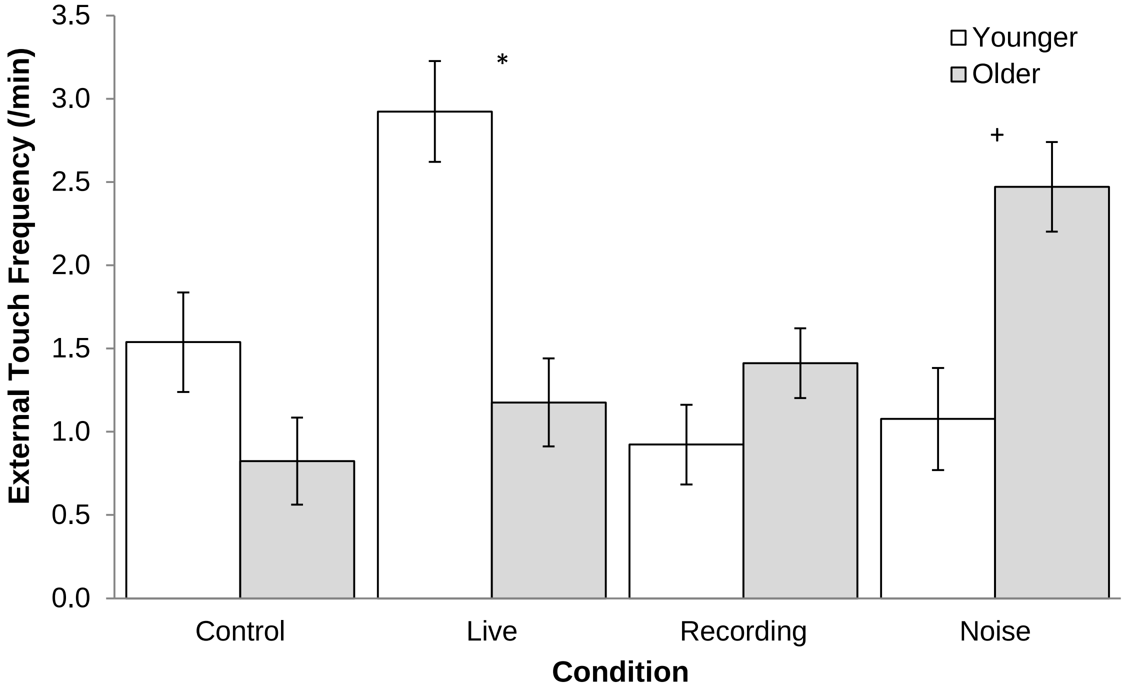

Figure 2.88. Average ‘External touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (* < .05).

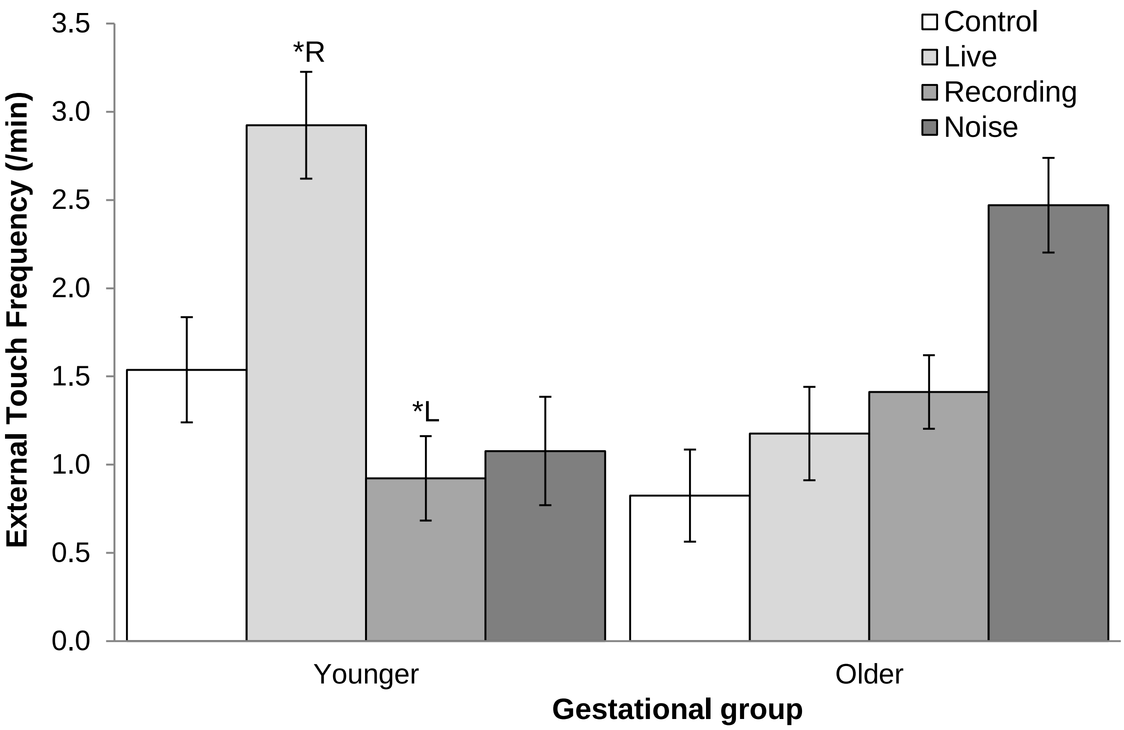

Figure 2.89. Average ‘External touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

60-90 Interval analysis

Repeated-measures ANOVA Condition: ‘Yawning’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Yawning’ frequency between the four Conditions (Control, Live, Recording, Noise). As the assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results indicate a trend between the four Conditions F (1.33, 38.51) = 2.90, p = .086, η_p^2 = .09. Examination of these means suggests that ‘Yawning’ frequency varied across Conditions. Polynomial contrasts indicated, in support of this, a cubic trend, F (1, 29) = 4.09, p = .053, η_p^2 = .12. Overall, there is a cubic trend produced by the means from ‘Control’ (M = 0.67) to the ‘Noise’ condition (M = 0.67) followed by lower means of ‘Live’ (M = 0.00) and ‘Recording’ (M = 0.47).

Post-hoc analysis showed no further tendencies to elaborate on the observed effect (see Figure 2.90). The means and standard errors can be examined in Table 2.54.

Table 2.54. Means and standard errors (SE) on fetal ‘Yawning’ frequency across conditions.

	Control	Live	Recording	Noise
Mean	0.07	0.00	0.47	0.07
SE	0.07	0.00	0.23	0.07

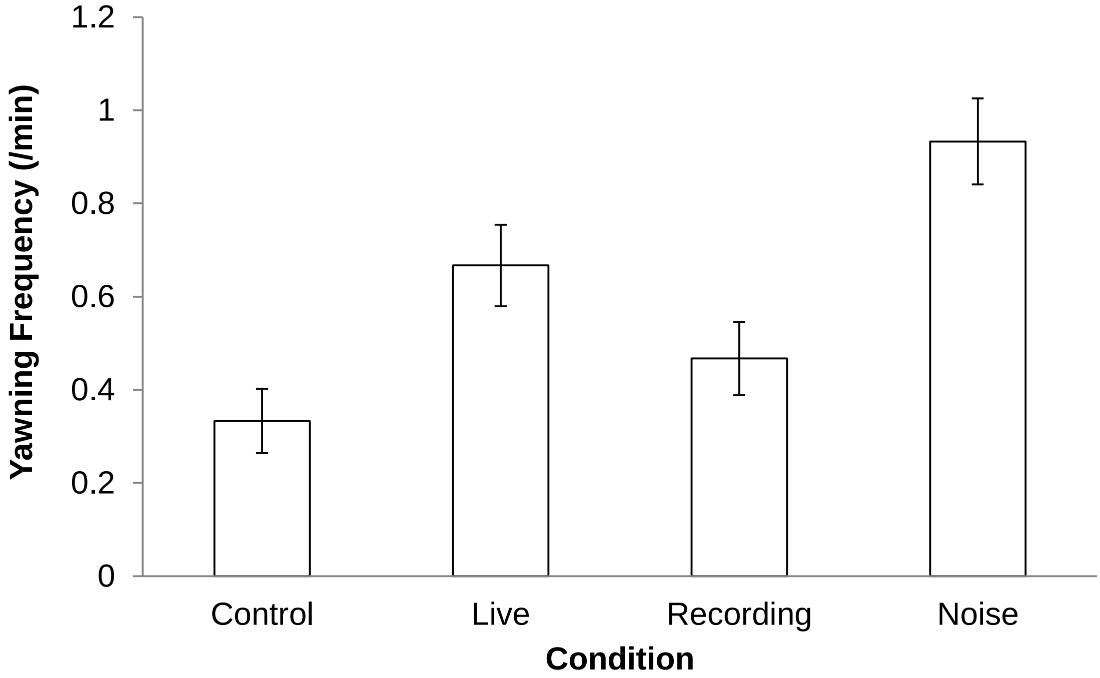

Figure 2.90. Average ‘Yawning’ frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: ‘Face press’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). As the assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results indicate a significant between the four Conditions F (2.50, 72.56) = 3.57, p = .024, η_p^2 = .11. Examination of these means suggests that ‘Face press’ frequency varied between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.75, p = .023, η_p^2 = .17. However, this finding was qualified by the significant cubic trend, F (1, 29) = 9.43, p = .005, η_p^2 = .25. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.33) to the ‘Noise’ condition (M = 0.93). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.47) than the ‘Live’ condition (M = 0.67) producing the cubic trend.

Post-hoc analysis of the main effect of Condition showed a significant between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ frequency in the

‘Noise’ (M = 0.93) condition compared to ‘Control’ (M = 0.33, p = .028) (see Figure 2.91). No further effects were found. The means and standard errors can be examined in Table 2.55.

Table 2.55. Means and standard errors (SE) on the frequency of fetuses ‘Face press’ of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	0.33	0.67	0.47	0.93
SE	0.14	0.18	0.16	0.19

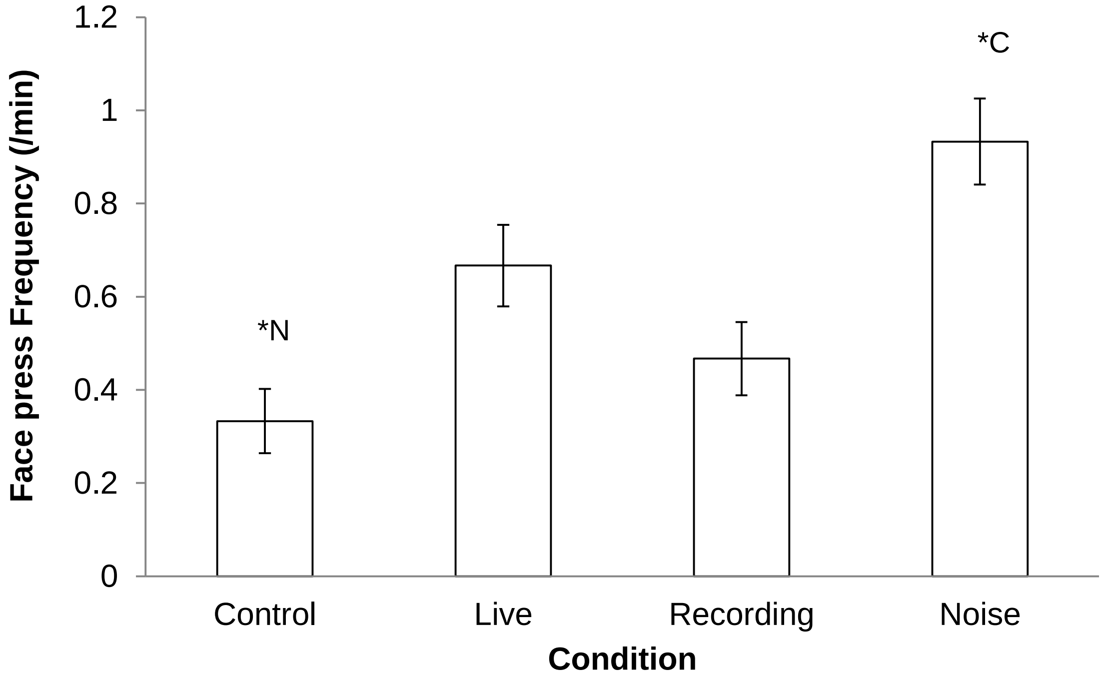

Figure 2.91. Average ‘Face press’ frequency (per minute) including standard errors for each condition (*< .05).

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in duration of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). Results indicate that there was a significant difference between the four Conditions F (2.5, 72.56) =

3.57, p = .024, η_p^2 = .11. Examination of these means suggests that the duration of fetuses touching the uterine wall with their face differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.75, p = .023, η_p^2 = .17. However, this finding was qualified by the significant cubic trend, F (1, 29) = 9.43, p = .005, η_p^2 = .25. Overall, there is a linear increase produced by the means from 'Control' (M = 16.67) to the 'Noise' condition (M = 46.67). However, the 'Recording' condition has a somewhat lower mean (M = 23.33) than the 'Live' condition (M = 33.33) producing the cubic trend.

Post-hoc analysis showed a significant difference between 'Noise' and 'Control', with fetuses increasing 'Face press' duration in the 'Noise' (M = 46.67) condition compared to 'Control' (M = 16.67, p = .028) (see Figure 2.92). No further effects were found. The means and standard errors can be examined in Table 2.56.

Table 2.56. Means and standard errors (SE) on the duration of fetuses 'Face press' of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	16.67	33.33	23.33	46.67
SE	6.92	8.75	7.85	9.26

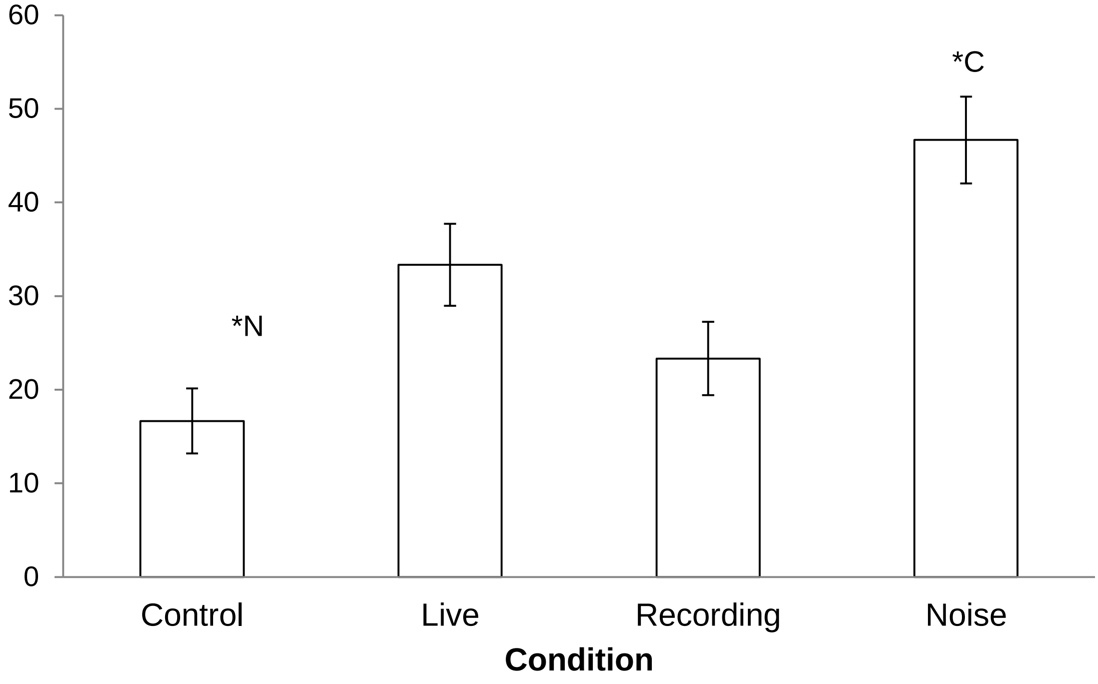

Figure 2.92. Average ‘Face press’ duration (per minute) including standard errors for each condition (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Arm Movement’ Frequency*

A mixed design ANOVA, using Huynh-Feldt correction, was conducted to assess differences in ‘Arm movement’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results showed a marginally significant interaction between Condition and GA, F (2.71, 75.74) = 2.42, p = .079, η_p^2 = .08. No main effects of Condition F (2.71, 75.74) = 1.46 p = .235, η_p^2 = .05, or GA F (1, 28) = 2.08, p = .160, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition F (1, 28) = 8.78, p = .006, η_p^2 = .24.

Post-hoc analysis of the interaction showed a significant difference of younger fetuses displaying more ‘Arm movements’ in ‘Live’ (M = 5.23) compared to older fetuses (M = 1.88, p = .006). Younger fetuses displayed significantly more ‘Arm movements’ in ‘Live’ (M = 5.23) compared to ‘Noise’ (M = 1.85, p = .005), the same tendency was observed between ‘Recording’ (M = 4.46) and ‘Noise’ (M = 1.85, p = .069) (see Figures 2.93 and 2.94). No further effects were found. The means and standard errors can be examined in Table 2.57.

Table 2.57. Means and standard errors (SE) of fetuses 'Arm movement' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.85	0.58	2.74	0.51		
Control	3.85	1.10	3.29	0.97	3.57	0.73
Live	5.23	0.85	1.88	0.75	3.56	0.57
Recording	4.46	1.03	3.06	0.90	3.76	0.68
Noise	1.85	0.72	2.71	0.63	2.28	0.47

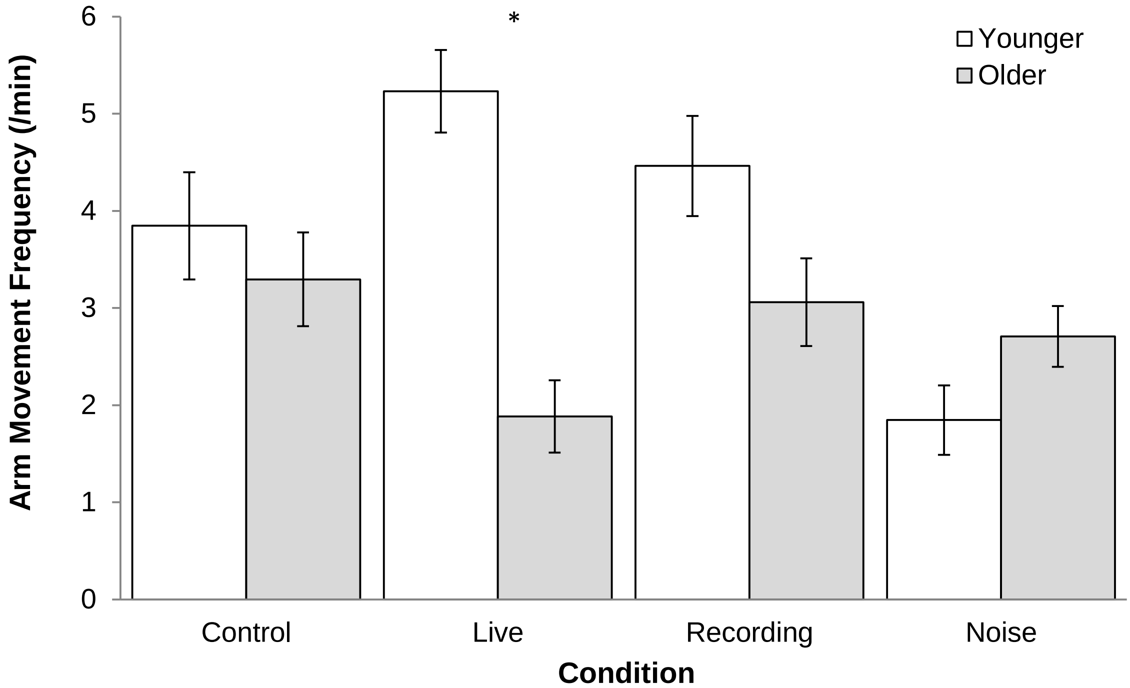

Figure 2.93. Average 'Arm movement' frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

Figure 2.94. Average ‘Arm movement’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

*Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Uterus touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a significant interaction between Condition and GA, F (3, 84) = 2.95, p = .038, η_p^2 = .10. No main effects of Condition F (3, 84) = 1.84 p = .146, η_p^2 = .06, or GA F (1, 28) = 0.94, p = .341, η_p^2 = .03, were found. In support of this, polynomial contrasts of the interaction indicated a significant linear trend F (1, 28) = 4.28, p = .048, η_p^2 = .13.

Post-hoc analysis of the interaction showed that younger fetuses (M = 1.85) touch the uterus significantly more in ‘Live’ compared to older fetuses (M = 0.35, p = .022). Younger fetuses displayed a tendency for increased ‘Uterus touch’ frequency in ‘Live’ (M = 1.85) compared to ‘Noise’ (M = 0.31, p = .084) (see Figures 2.95 and 2.96). No further effects were found. The means and standard errors can be examined in Table 2.58.

Table 2.58. Means and standard errors (SE) of fetuses 'Uterus touch' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.00	0.25	0.68	0.22		
Control	0.77	0.35	0.24	0.30	0.50	0.23
Live	1.85	0.46	0.35	0.40	1.10	0.31
Recording	1.08	0.53	1.29	0.46	1.19	0.35
Noise	0.31	0.33	0.82	0.29	0.57	0.22

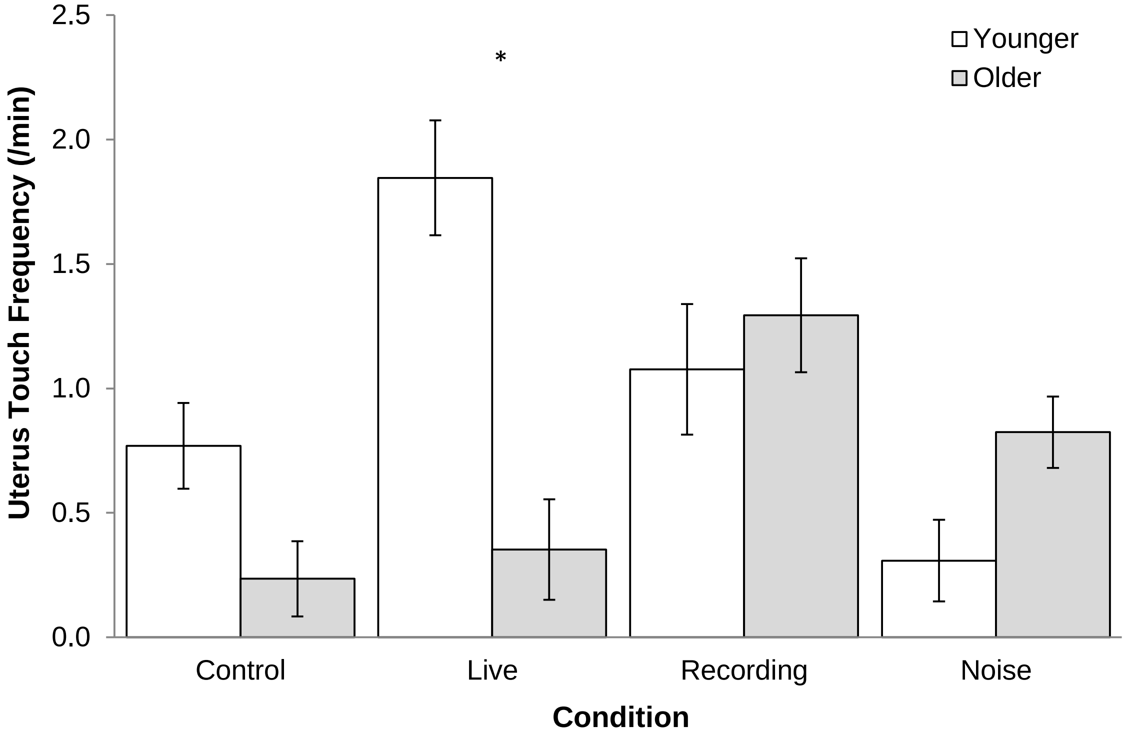

Figure 2.95. Average 'Uterus touch' frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

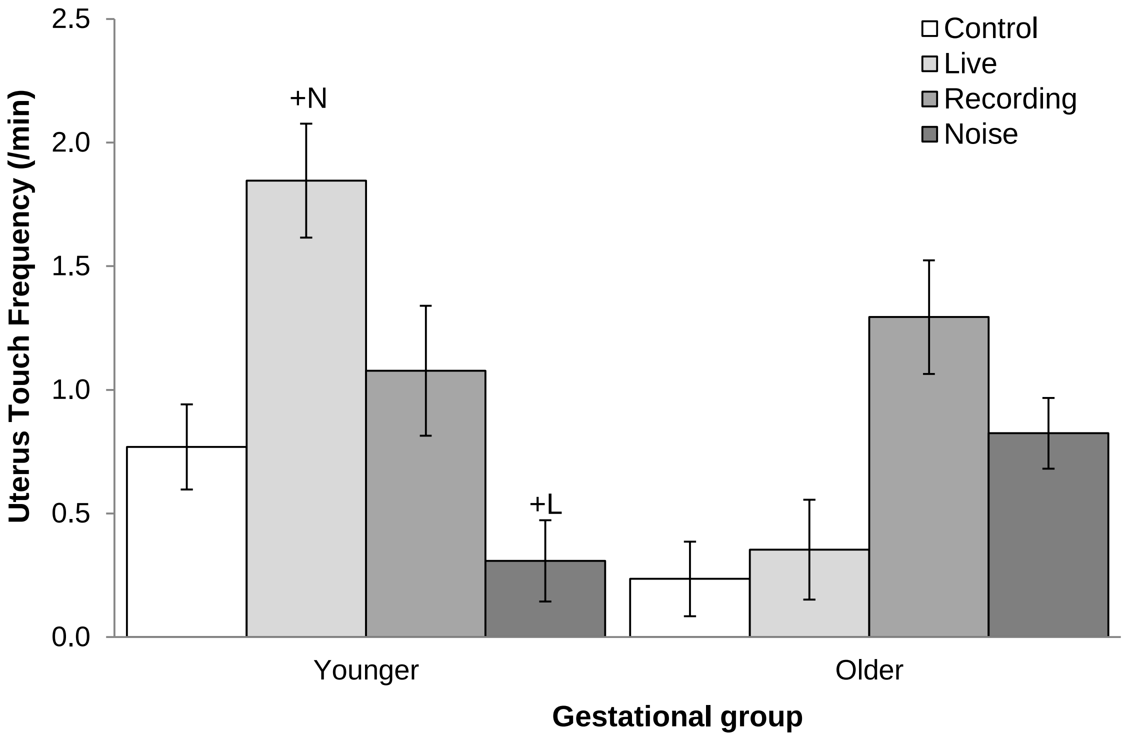

Figure 2.96. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences in ‘Face press’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicate a significant Condition main effect, F (3, 84) = 3.39, p = .029, η_p^2 = .11. No main effects of GA F (1, 28) = 0.22 p = .644, η_p^2 = .01, or an interaction F (3, 84) = 0.91, p = .438, η_p^2 = .03, were found. In support of this polynomial contrasts of Condition indicated a significant linear trend F (1, 28) = 5.21, p = .030, η_p^2 = .16, which is qualified by a significant cubic trend F (1, 28) = 8.58, p = .007, η_p^2 = .24. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.35) to the ‘Noise’ condition (M = 0.93). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.45) than the ‘Live’ condition (M = 0.64) producing the cubic trend. Post-hoc analysis of the main effect of Condition showed a significant difference between ‘Control’ and ‘Noise’ with a higher ‘Face press’ frequency in ‘Noise’ (M

= 0.93) compared to ‘Control’ (M = 0.35, *p* = .040) (see Figure 2.97). No further effects were found. The means and standard errors can be examined in Table 2.59.

Table 2.59. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.54	0.18	0.65	0.15		
Control	0.46	0.21	0.24	0.19	0.35	0.14
Live	0.46	0.27	0.82	0.23	0.64	0.18
Recording	0.31	0.24	0.59	0.21	0.45	0.16
Noise	0.92	0.29	0.41	0.25	0.93	0.19

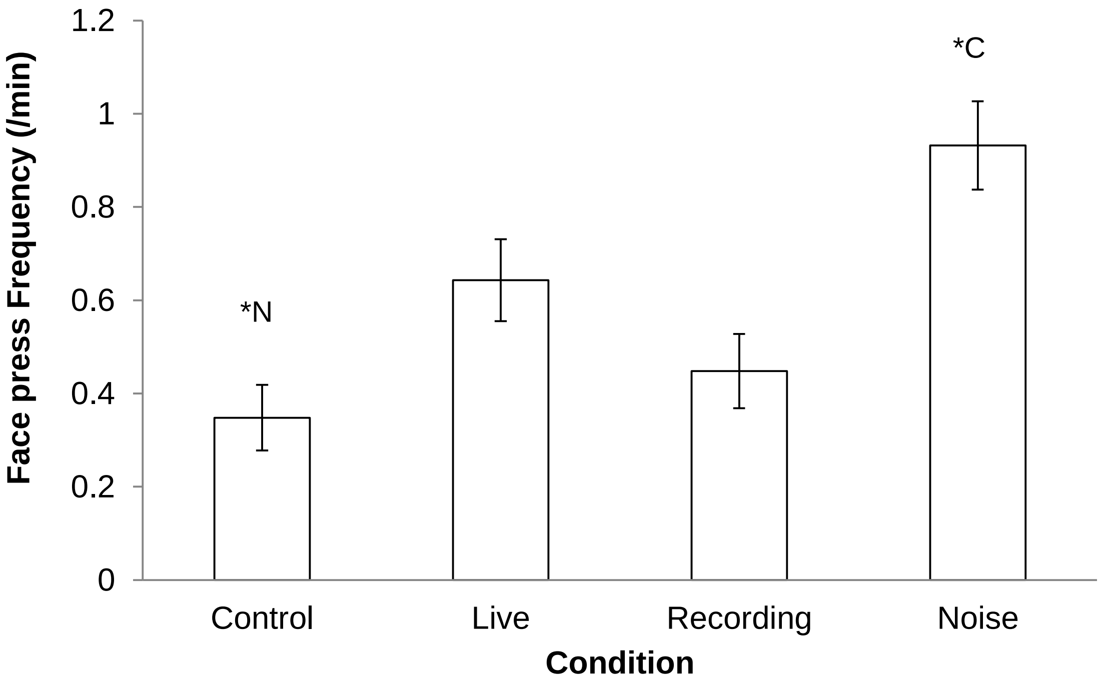

Figure 2.97. Average ‘Face press’ frequency (per minute) including standard errors for each condition (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘Face press’ duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results show a significant main effect of Condition F (2.56, 71.79) = 3.39, p = .029, η_p^2 = .11. No main effects of GA F (1, 28) = 0.22 p = .644, η_p^2 = .01, or an interaction F (2.56, 71.79) = 0.91, p = .426, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 5.21, p = .030, η_p^2 = .16, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 28) = 8.58, p = .007, η_p^2 = .24. Overall, there is a linear increase produced by the means from ‘Control’ (M = 17.42) to the ‘Noise’ condition (M = 46.61). However, the ‘Recording’ condition has a somewhat lower mean (M = 22.40) than the ‘Live’ condition (M = 32.13) producing the cubic trend.

Post-hoc analysis of the main effect of Condition showed a significant difference between ‘Control’ and ‘Noise’ with a longer duration of ‘Face press’ in ‘Noise’ (M = 46.61) compared to ‘Control’ (M = 17.42, p = .040) (see Figure 2.98). No further effects were found. The means and standard errors can be examined in Table 2.60.

Table 2.60. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	26.92	8.74	32.35	7.64		
Control	23.08	10.58	11.77	9.25	17.42	7.03
Live	23.08	13.29	41.17	11.62	32.13	8.83
Recording	15.39	11.98	29.41	10.47	22.40	7.96
Noise	46.15	14.32	47.06	12.52	46.61	9.51

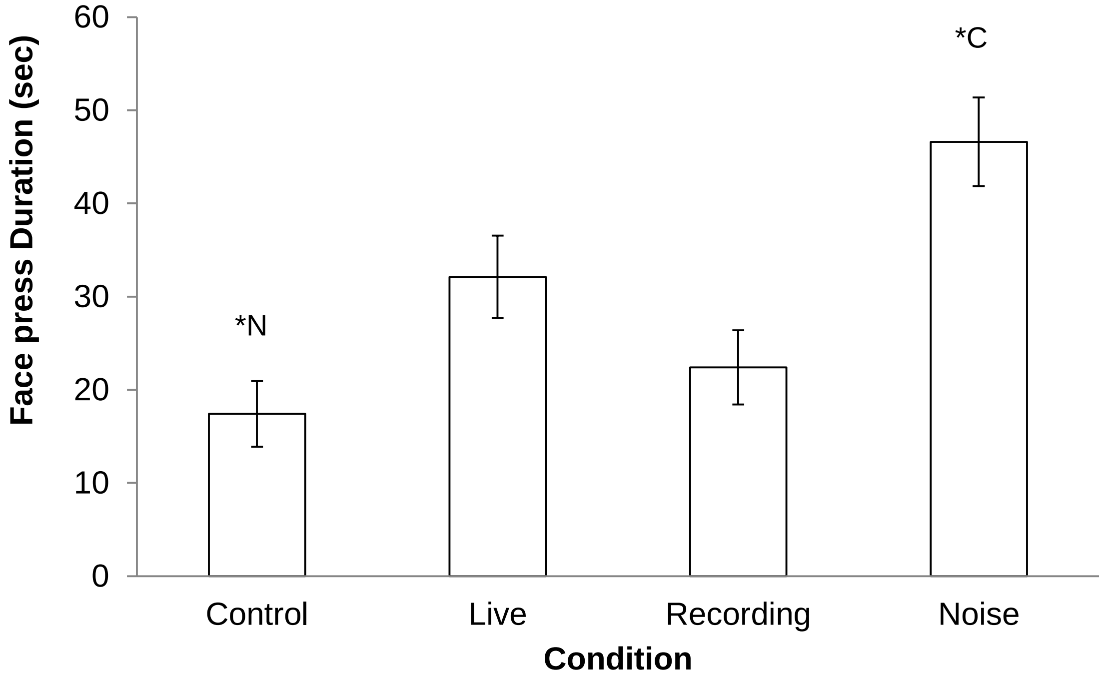

Figure 2.98. Average ‘Face press’ duration (per minute) including standard errors for each condition (*< .05).

60-90 Interval analysis combined

Repeated-measures ANOVA Condition: ‘Self-touch’ Frequency

A repeated-measures ANOVA was conducted to assess differences in ‘Self-touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results show a marginally significant effect of Condition, F (3, 87) = 2.37, p = .077, η_p^2 = .08. In support of this polynomial contrasts indicated a significant linear trend F (1, 29) = 4.96, p = .034, η_p^2 = .15. Overall, there is a linear increase produced by the means from ‘Control’ (M = 1.67), over ‘Live’ (M = 1.93) to ‘Recording’ (M = 2.93) followed by a decrease to the ‘Noise’ condition (M = 2.53), producing the linear trend.

Post-hoc analysis showed a significant difference between ‘Control’ and ‘Recording’ with a higher ‘Face press’ frequency in ‘Recording’ (M = 2.93) compared to ‘Control’ (M = 1.67, p = .034) (see Figure 2.99). No further effects were found. The means and standard errors can be examined in Table 2.61.

Table 2.61. Means and standard errors (SE) on the frequency of Self-touch' of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	1.67	1.93	2.93	2.53
SE	0.24	0.31	0.48	0.51

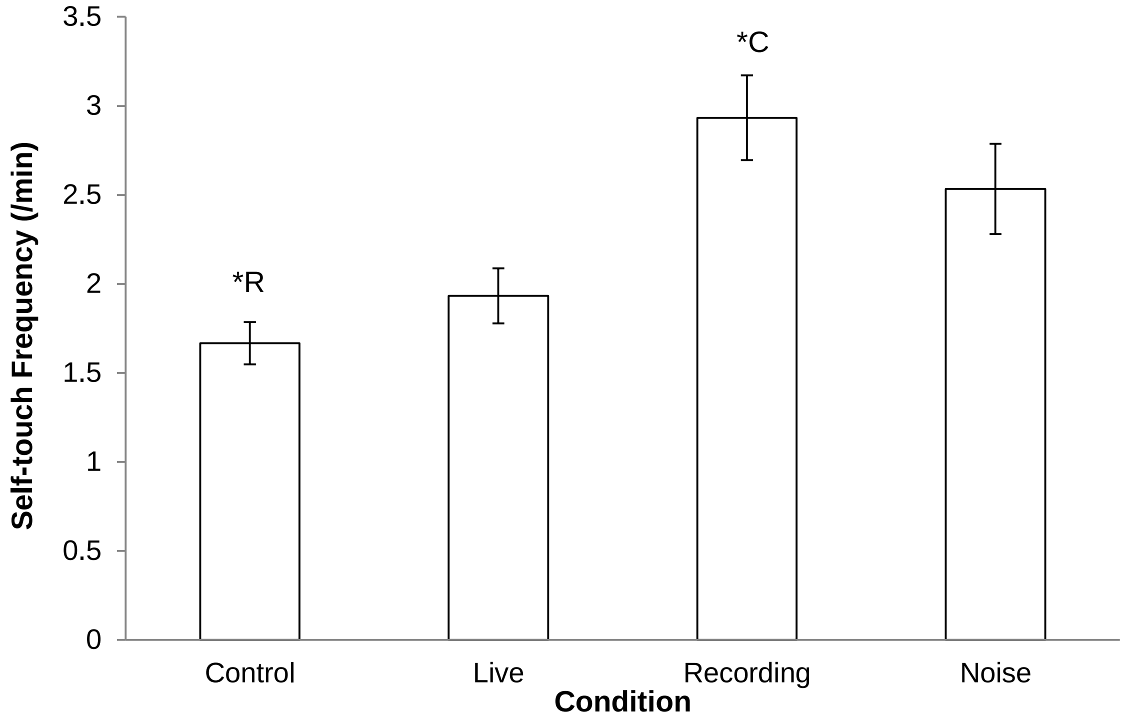

Figure 2.99. Average 'Self-touch' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

60-120 Interval analysis

Repeated-measures ANOVA Condition: 'Face press' Frequency

A repeated-measures ANOVA was conducted, using Huynh-Feldt correction, to assess differences in 'Face press' frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results show a significant effect of Condition, F (2.51, 72.89) = 3.46, p = .027, η_p^2 = .11. In support of this polynomial contrasts indicated a significant linear trend F (1, 29) = 5.44, p = .027, η_p^2 = .16. This finding is qualified by the significant cubic trend of Condition, F (1, 29) = 9.25, p = .005, η_p^2 = .24. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.17) to the ‘Noise’ condition (M = 0.47). However, the ‘Recording’ condition has a somewhat lower mean (M = .23) than the ‘Live’ condition (M = 0.33) producing the cubic trend.

Post-hoc analysis showed a significant difference between ‘Control’ and ‘Noise’ with a higher ‘Face press’ frequency in ‘Noise’ (M = 0.47) compared to ‘Control’ (M = 0.17, *p* = .034) (see Figure 2.100). No further effects were found. The means and standard errors can be examined in Table 2.62.

Table 2.62. Means and standard errors (SE) on the frequency of ‘Face press’ against the uterus across conditions.

	Control	Live	Recording	Noise
Mean	0.17	0.33	0.23	0.47
SE	0.07	0.09	0.08	0.09

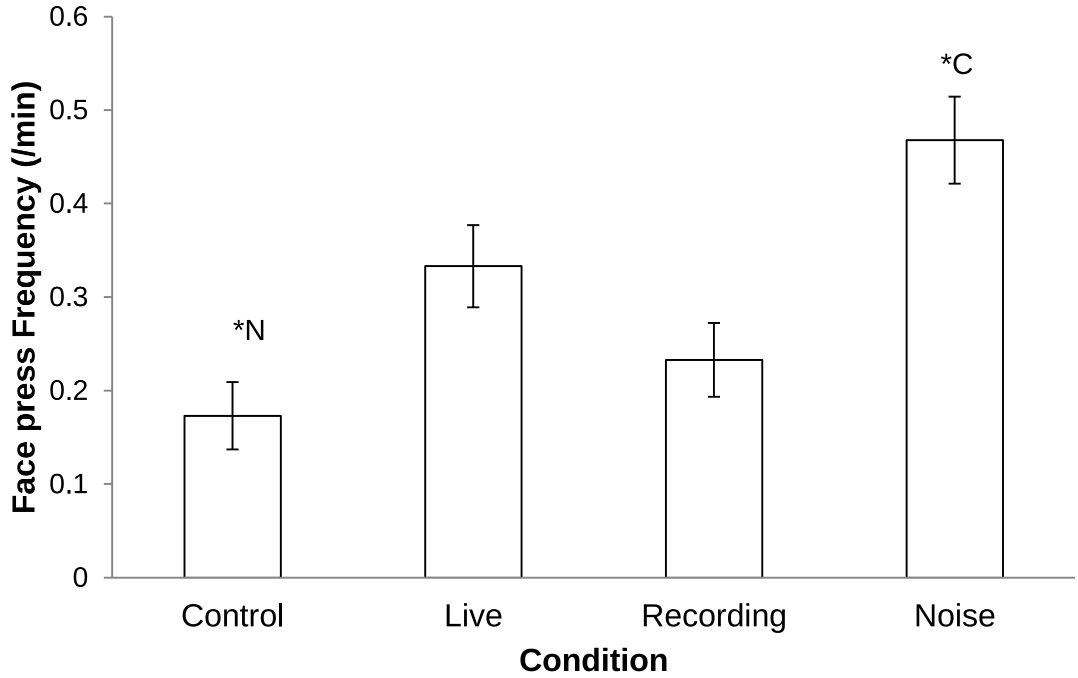

Figure 2.100. Average ‘Face press’ frequency (per minute) including standard errors for each condition (*< .05).

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in duration of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). Results indicate that there was a significant difference in ‘Face press’ duration between the four Conditions F (2.29, 72.55) = 3.58, p = .024, η_p^2 = .11. Examination of these means suggests that ‘Face press’ duration differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.75, p = .023, η_p^2 = .17. However, this finding was qualified by the significant cubic trend, F (1, 29) = 9.49, p = .004, η_p^2 = .25. Overall, there is a linear increase produced by the means from ‘Control’ (M = 16.66) to the ‘Noise’ condition (M = 46.66). However, the ‘Recording’ condition has a somewhat lower mean (M = 23.26) than the ‘Live’ condition (M = 33.33) producing the cubic trend.

Post-hoc analysis revealed a significant difference between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ duration in the ‘Noise’ (M = 46.66) condition compared to ‘Control’ (M = 16.66, p = .028) (see Figure 2.101). No further effects were found. The means and standard errors can be examined in Table 2.63.

Table 2.63. Means and standard errors (SE) on the duration of ‘Face press’ against the uterus across conditions.

	Control	Live	Recording	Noise
Mean	16.66	33.33	23.26	46.66
SE	6.92	8.75	7.83	9.26

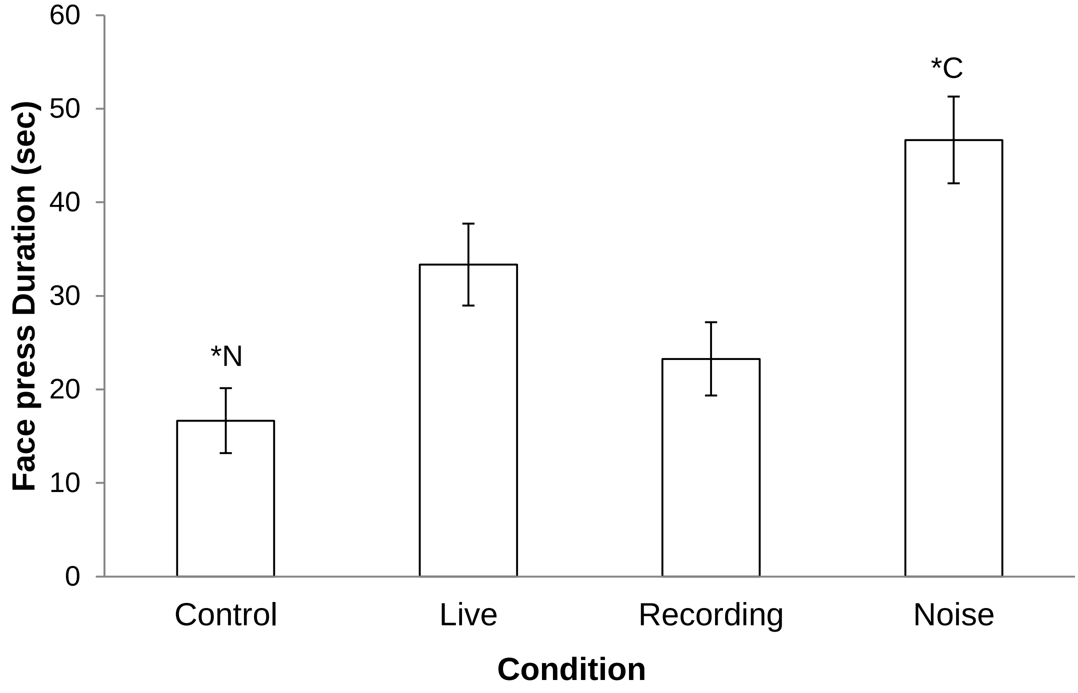

Figure 2.101. Average ‘Face press’ duration (in seconds) including standard errors for each condition (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences in ‘Face press’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicate a significant Condition main effect, F (2.57, 71.90) = 3.28, p = .032, η_p^2 = .11. No main effects of GA F (1, 28) = 0.19 p = .666, η_p^2 = .01, or an interaction F (2.57, 71.90) = 0.99, p = .393, η_p^2 = .03, were found. In support of this polynomial contrasts of Condition indicated a significant linear trend F (1, 28) = 4.89, p = .035, η_p^2 = .15, which is qualified by a significant cubic trend F (1, 28) = 8.40, p = .007, η_p^2 = .23. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.18) to the ‘Noise’ condition (M = 0.47). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.22) than the ‘Live’ condition (M = 0.32) producing the cubic trend.

Post-hoc analysis of the main effect of Condition showed a trend between ‘Control’ and ‘Noise’ with a higher ‘Face press’ frequency in ‘Noise’ (M = 0.47) compared to ‘Control’ (M = 0.18, p = .050) (see Figure 2.102). No further effects

Table 2.64. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and GA as well as pairwise comparisons.

were found. The means and standard errors can be examined in Table 2.64.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.27	0.09	0.32	0.08		
Control	0.25	0.11	0.12	0.10	0.18	0.07
Live	0.23	0.13	0.41	0.12	0.32	0.09
Recording	0.15	0.12	0.29	0.11	0.22	0.80
Noise	0.46	0.14	0.47	0.13	0.47	0.10

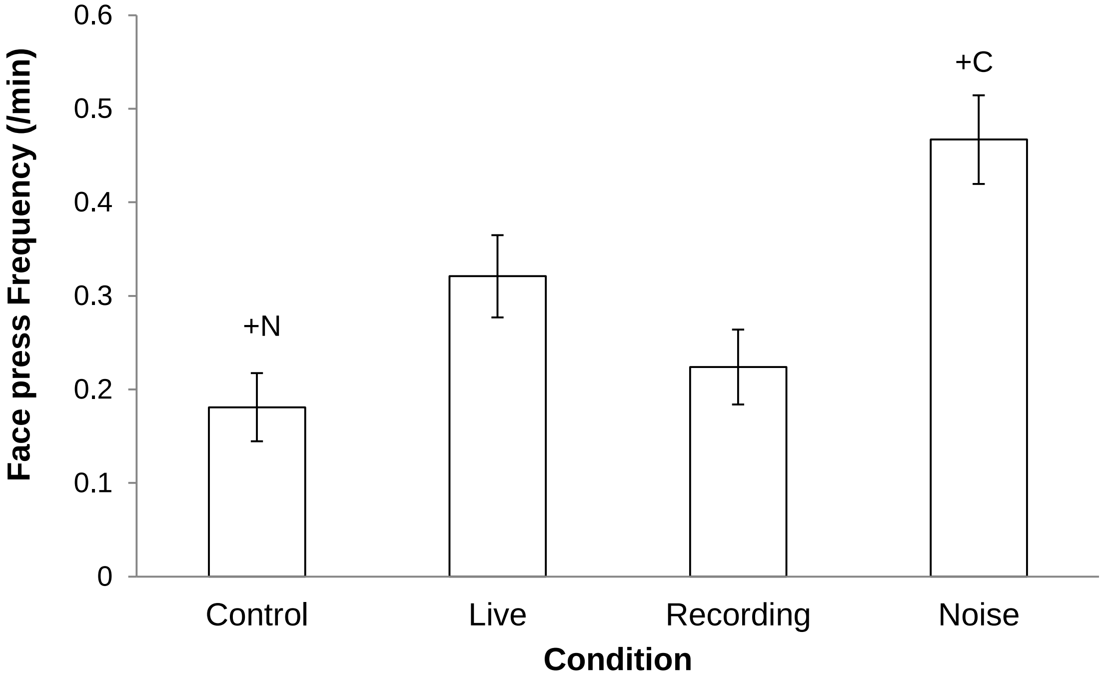

Figure 2.102. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Face press' Duration*

A mixed design ANOVA was conducted to assess differences in 'Face press' duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results show a significant main effect of Condition F (2.56, 71.77) = 3.40, p = .028, η_p^2 = .11. No main effects of GA F (1, 28) = 0.22 p = .645, η_p^2 = .01, or an interaction F (2.56, 71.77) = 0.91, p = .427, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 5.20, p = .030, η_p^2 = .16, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 28) = 8.63, p = .007, η_p^2 = .24. Overall, there is a linear increase produced by the means from 'Control' (M = 17.42) to the 'Noise' condition (M = 46.60). However, the 'Recording' condition has a somewhat lower mean (M = 22.33) than the 'Live' condition (M = 32.13) producing the cubic trend

Post-hoc analysis of the main effect of Condition showed a significant difference between 'Control' and 'Noise' with a longer duration of 'Face press' in 'Noise' (M = 46.60) compared to 'Control' (M = 17.42, p = .040) (see Figure 2.103). No further effects were found. The means and standard errors can be examined in Table 2.65.

Table 2.65. Means and standard errors (SE) of fetuses 'Face press' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	26.92	8.73	32.32	7.63		
Control	23.07	10.58	11.77	9.25	17.42	7.03
Live	23.08	13.29	41.17	11.62	32.13	8.82
Recording	15.37	11.94	29.29	10.44	22.33	7.93
Noise	46.15	14.32	47.05	12.52	46.60	9.51

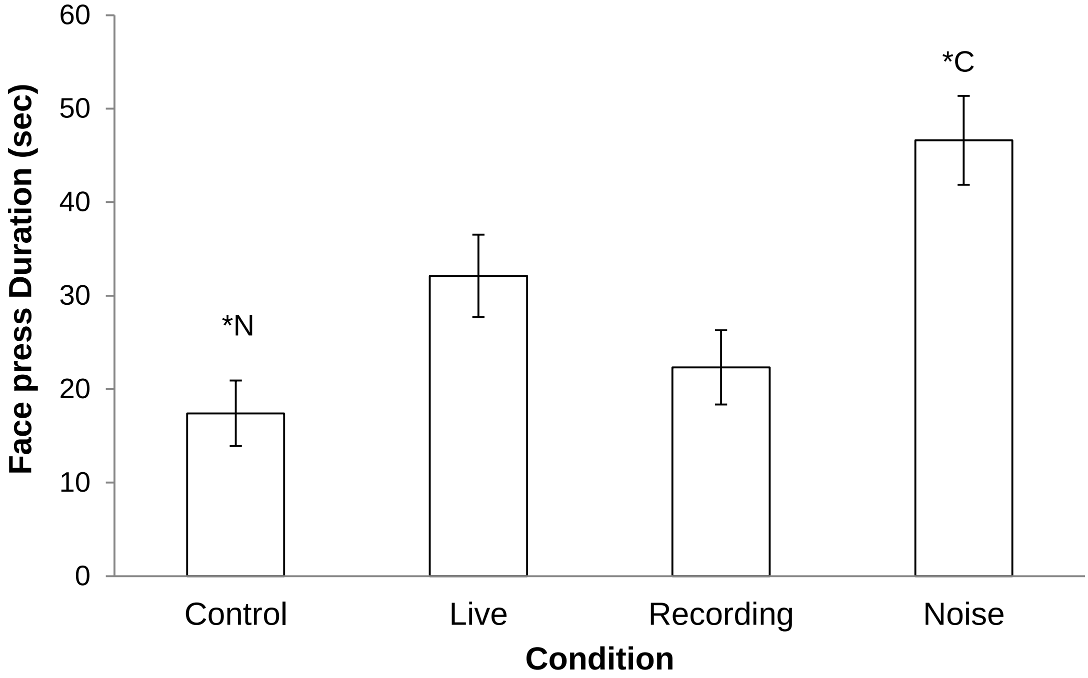

Figure 2.103. Average 'Face press' duration (in seconds) including standard errors for each condition (*< .05).

60-120 Interval analysis

*Mixed-design ANOVA Condition*GA: 'General Movement' Frequency*

A mixed design ANOVA was conducted to assess differences in 'General movement' frequency and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effect of Condition F (3, 84) = 0.59, p = .623, η_p^2 = .02, and interaction between Condition and GA, F (3, 84) = 0.59, p = .625, η_p^2 = .02. However, a significant main effect of GA F (1, 28) = 14.97, p = .001, η_p^2 = .35, was found.

Post-hoc analysis of the main effect of GA showed a significant difference between younger and older fetuses with younger fetuses (M = 7.01) displaying increased 'General movement' frequencies compared to older fetuses (M = 3.80, p = .001) (see Figure 2.104). No further effects were found. The means and standard errors can be examined in Table 2.66.

Table 2.66. Means and standard errors (SE) of fetuses ‘General movement’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.01	0.63	3.80	0.55		
Control	6.86	1.38	3.83	1.21	5.34	0.92
Live	7.16	1.46	4.89	1.28	6.02	0.97
Recording	8.32	1.09	3.18	0.96	5.75	0.73
Noise	5.70	1.20	3.29	1.05	4.50	0.80

Figure 2.104. Average ‘General movement’ frequency (per minute) including standard errors for GA (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: 'General Movement' Duration*

A mixed design ANOVA was conducted to assess differences in 'General movement' duration and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effect of Condition F (3, 84) = 0.55, p = .651, η_p^2 = .02, and interaction between Condition and GA, F (3, 84) = 0.89, p = .449, η_p^2 = .03. However, a significant main effect of GA F (1, 28) = 6.13, p = .020, η_p^2 = .18, was found.

Post-hoc analysis of the main effect of GA showed a significant difference between younger and older fetuses with younger fetuses (M = 3.60) displaying longer 'General movement' durations compared to older fetuses (M = 1.89, p = .020) (see Figure 2.105). No further effects were found. The means and standard errors can be examined in Table 2.67.

Table 2.67. Means and standard errors (SE) of fetuses 'General movement' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.60	0.52	1.89	0.45		
Control	3.18	0.81	1.86	0.71	2.52	0.54
Live	3.89	0.60	1.07	0.52	2.48	0.40
Recording	4.48	1.03	2.23	0.90	3.36	0.68
Noise	2.84	1.05	2.42	0.92	2.63	0.70

Figure 2.105. Average ‘General movement’ duration (in seconds) including standard errors for GA (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Inactivity/Resting’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Inactivity/Resting’ frequency and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed a marginally significant main effect of Condition F (3, 84) = 2.51, p = .064, η_p^2 = .08. No significant interaction between Condition and GA, F (3, 84) = 2.11, p = .105, η_p^2 = .07, or main effect of GA F (1, 28) = 0.63, p = .434, η_p^2 = .02. In support of this polynomial contrasts of Condition indicated a significant linear trend F (1, 28) = 5.93, p = .021, η_p^2 = .18. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.26) and ‘Live’ (M = 0.26) to ‘Recording’ (M = 0.61). However, the ‘Noise’ condition (M = 0.56) has a somewhat lower mean producing the linear trend.

Post-hoc analysis of the main effect of Condition revealed no further effects (see Figure 2.106). No further effects were found. The means and standard errors can be examined in Table 2.68.

Table 2.68. Means and standard errors (SE) of fetuses 'Inactivity/Resting' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.48	0.11	0.37	0.09		
Control	0.23	0.13	0.29	0.11	0.26	0.08
Live	0.23	0.15	0.29	0.13	0.26	0.10
Recording	0.92	0.27	0.29	0.24	0.61	0.18
Noise	0.54	0.18	0.59	0.15	0.56	0.12

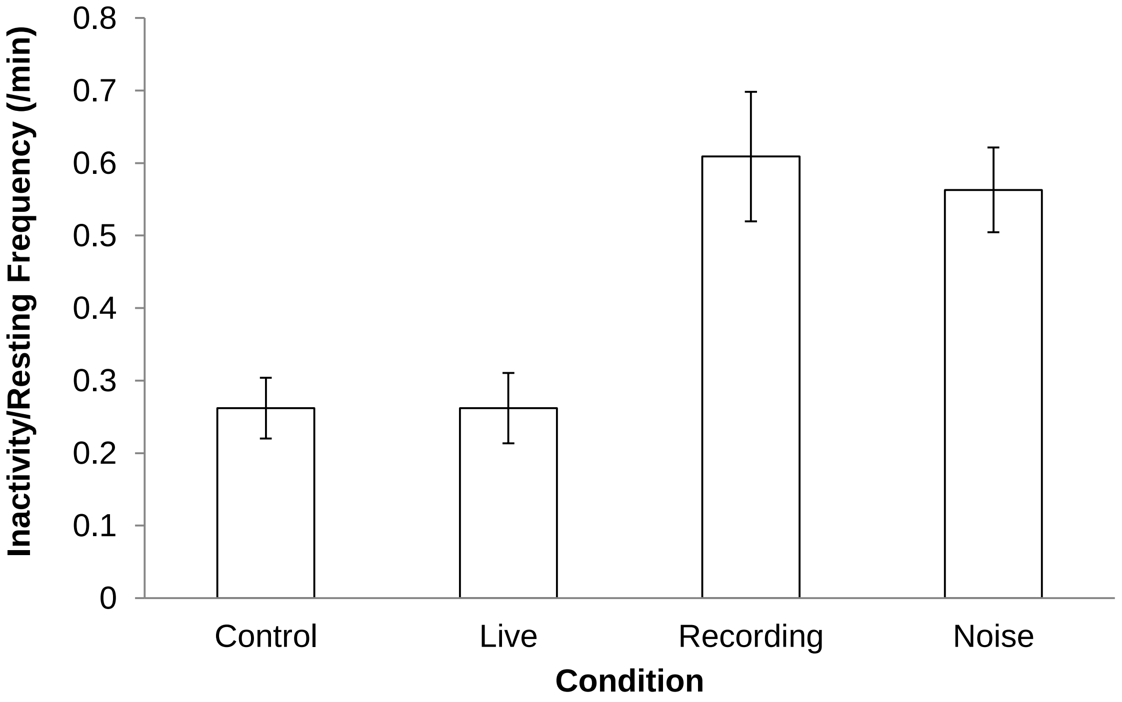

Figure 2.106. Average 'Inactivity/Resting' frequency (per minute) including standard errors for each condition.

90-120 Interval analysis

Repeated-measures ANOVA Condition: 'Face press' Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the 'Face press' between the four Conditions (Control, Live, Recording, Noise). As the assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results indicate a significant difference between the Conditions F (2.54, 73.75) = 3.28, p = .032, η_p^2 = .10. Examination of these means suggests that fetuses 'Face press' frequency changed depending on Condition. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 4.97, p = .034, η_p^2 = .15. However, this finding was qualified by the significant cubic trend, F (1, 29) = 8.97, p = .006, η_p^2 = .24. Overall, there is a linear increase produced by the means from 'Control' (M = 0.36) to the 'Noise' condition (M = 0.94). However, the 'Recording' condition has a somewhat lower mean (M = 0.47) than the 'Live' condition (M = 0.67) producing the cubic trend.

Post-hoc analysis of the main effect of Condition showed a significant difference between 'Noise' and 'Control', with fetuses increasing 'Face press' frequency in the 'Noise' (M = 0.94) condition compared to 'Control' (M = 0.36, p = .0.48(see Figure 2.107). No further effects were found. The means and standard errors can be examined in Table 2.69.

Table 2.69. Means and standard errors (SE) on the frequency of fetuses 'Face press' of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	0.36	0.67	0.47	0.94
SE	0.15	0.18	0.16	0.19

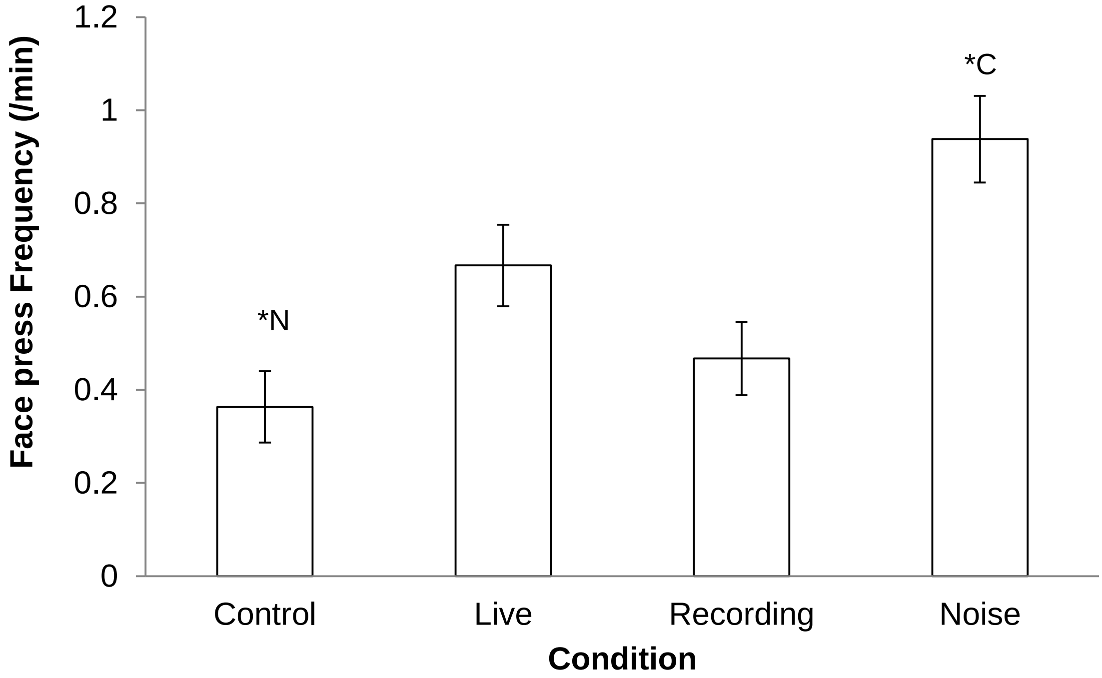

Figure 2.107. Average ‘Face press’ frequency (per minute) including standard errors for each condition (*< .05).

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA, with Huynh-Feldt correction, was conducted to assess whether there are differences in duration of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). Results indicate that there was a significant difference in ‘Face press’ duration between the four Conditions F (2.29, 72.54) = 3.59, p = .024, η_p^2 = .11. Examination of these means suggests that fetuses ‘Face press’ duration changed depending on Condition. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 29) = 5.74, p = .023, η_p^2 = .17. However, this finding was qualified by the significant cubic trend, F (1, 29) = 9.55, p = .004, η_p^2 = .25. Overall, there is a linear increase produced by the means from ‘Control’ (M = 16.66) to the ‘Noise’ condition (M = 46.66). However, the ‘Recording’ condition has a somewhat lower mean (M = 23.18) than the ‘Live’ condition (M = 33.33) producing the cubic trend.

Post-hoc analysis revealed a significant difference between ‘Noise’ and ‘Control’, with fetuses ‘Face press’ duration increasing in the ‘Noise’ (M = 46.66) condition compared to 'Control' (M = 16.66, *p* = .028) (see Figure 2.108). No further effects were found. The means and standard errors can be examined in Table 2.70.

Table 2.70. Means and standard errors (SE) on the duration of fetuses 'Face press' of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	16.66	33.33	23.18	46.66
SE	6.92	8.75	7.80	9.26

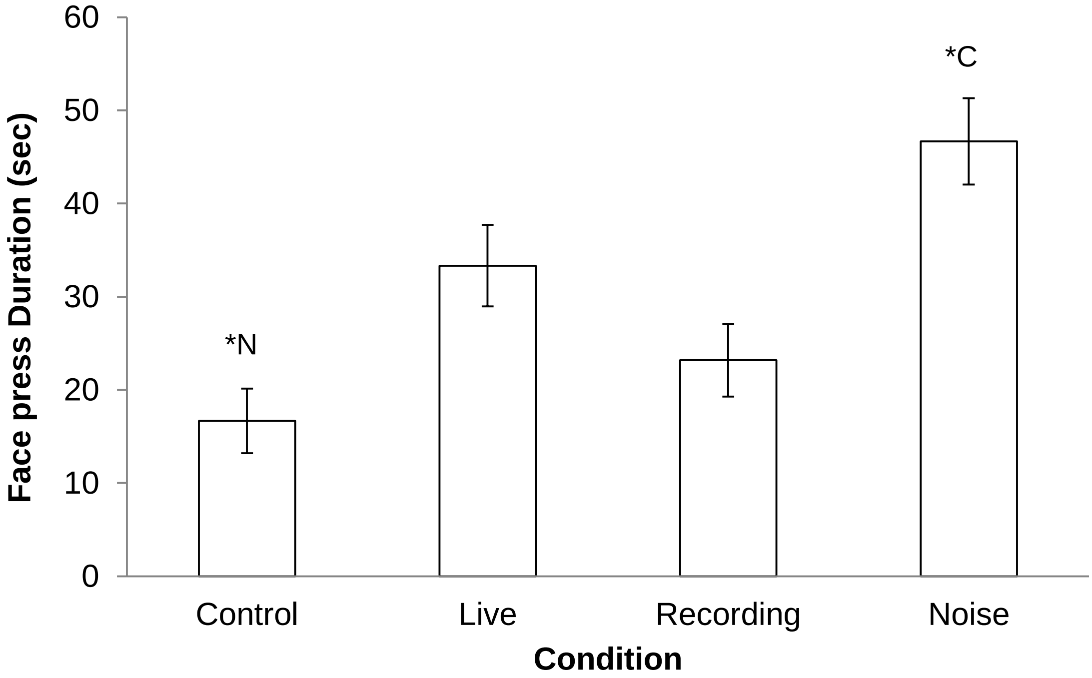

Figure 2.108. Average 'Face press' duration (per minute) including standard errors for each condition (*< .05).

*Mixed-design ANOVA Condition*GA: 'Arms-crossed' Frequency*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences of 'Arms-crossed' frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicate a significant interaction, F (2.63, 73.51) = 3.00, p = .043, η_p^2 = .10. No main effect of

Condition *F* (2.63, 73.51) = 1.23 *p* = .303, η_p^2 = .04, or GA *F* (1, 28) = 1.52, *p* = .227, η_p^2 = .05, were found. In support of this polynomial contrasts of the interaction indicated a significant quadratic trend *F* (1, 28) = 4.48, *p* = .043, η_p^2 = .14, which is qualified by a significant cubic trend *F* (1, 28) = 4.29, *p* = .048, η_p^2 = .13.

Post-hoc analysis of the interaction showed a significant difference in the 'Recording' condition with younger fetuses (M = 1.23) displaying more 'Arms-crossed' compared to older fetuses (M = 0.71, *p* = .009). Younger fetuses displayed significantly more 'Arms-crossed' behaviours in 'Recording' (M = 1.23) compared to 'Control' (M = 0.31, *p* = .015), the same tendency can be observed between 'Recording' (M = 1.23) and 'Live' (M = 0.31, *p* = .060) with more 'Arms-crossed' behaviours in 'Recording' compared to 'Live' (see Figures 2.109 and 2.110). No further effects were found. The means and standard errors can be examined in Table 2.71.

Table 2.71. Means and standard errors (SE) of fetuses 'Arms-crossed' behaviour frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.58	0.14	0.35	0.12		
Control	0.31	0.21	0.35	0.19	0.33	0.14
Live	0.31	0.20	0.24	0.17	0.27	0.13
Recording	1.23	0.30	0.12	0.26	0.68	0.20
Noise	0.46	0.34	0.71	0.29	0.58	0.22

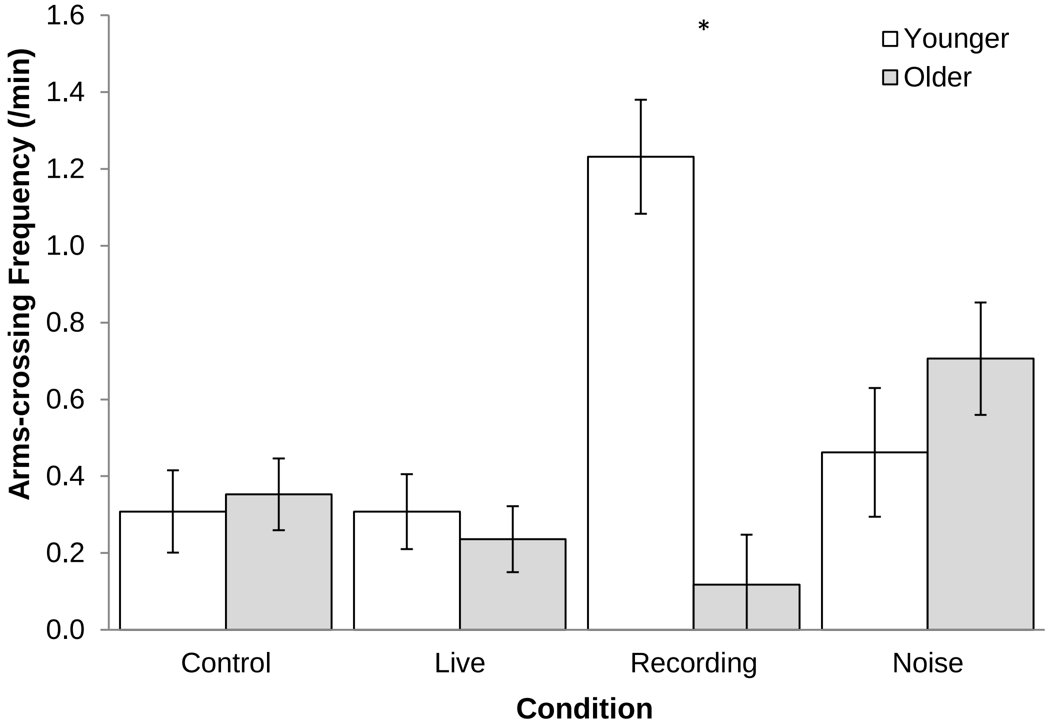

Figure 2.109. Average ‘Arms-crossed’ behaviour frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

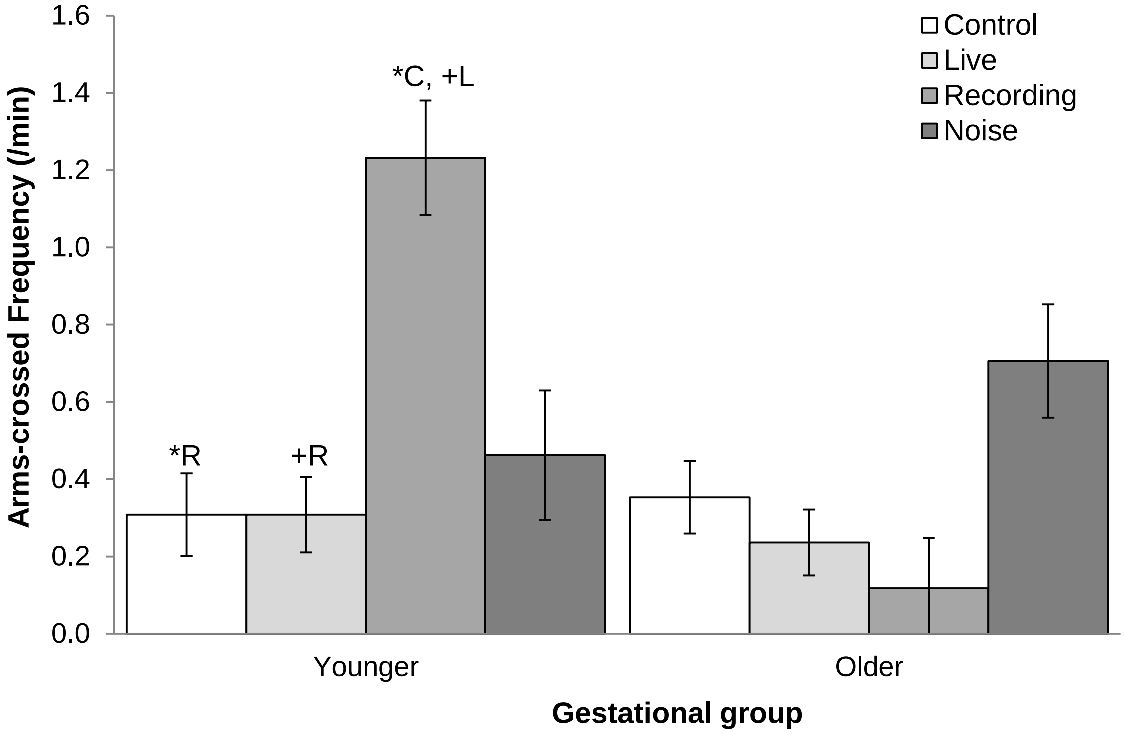

Figure 2.110. Average ‘Arms-crossed’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

*Mixed-design ANOVA Condition*GA: ‘Arms-crossed’ Duration*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences of ’Arms-crossed’ duration and GA across the four Conditions (Control, Live, Recording, Noise). Results indicate a trend for the interaction, F (2.86, 80.07) = 2.25, p = .092, η_p^2 = .07. No main effects of Condition F (2.86, 80.07) = 0.45 p = .707, η_p^2 = .02, or GA F (1, 28) = 0.89, p = .357, η_p^2 = .03, were found. In support of this polynomial contrasts of the interaction indicated a significant quadratic trend F (1, 28) = 5.51, p = .026, η_p^2 = .16.

Post-hoc analysis of the interaction showed a significant difference in the ‘Recording’ condition, with younger fetuses (M = 40.37) displaying an increased duration of ’Arms crossed’ behaviour compared to older fetuses (M = 5.88, p = .009). Younger fetuses displayed longer ‘Arms-crossed’ behaviours in ‘Recording’ (M = 40.37) compared to ‘Control’ (M = 14.32, p = .063) (see Figures 2.111 and 2.112). No further effects were found. The means and standard errors can be examined in Table 2.72.

Table 2.72. Means and standard errors (SE) of fetuses ‘Arms-crossed’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	20.70	5.25	14.13	4.59		
Control	14.32	9.52	14.17	8.33	14.24	6.33
Live	15.39	9.75	11.77	8.52	13.58	6.47
Recording	40.37	10.22	5.88	8.94	23.12	6.79
Noise	12.73	10.77	24.69	9.41	18.71	7.15

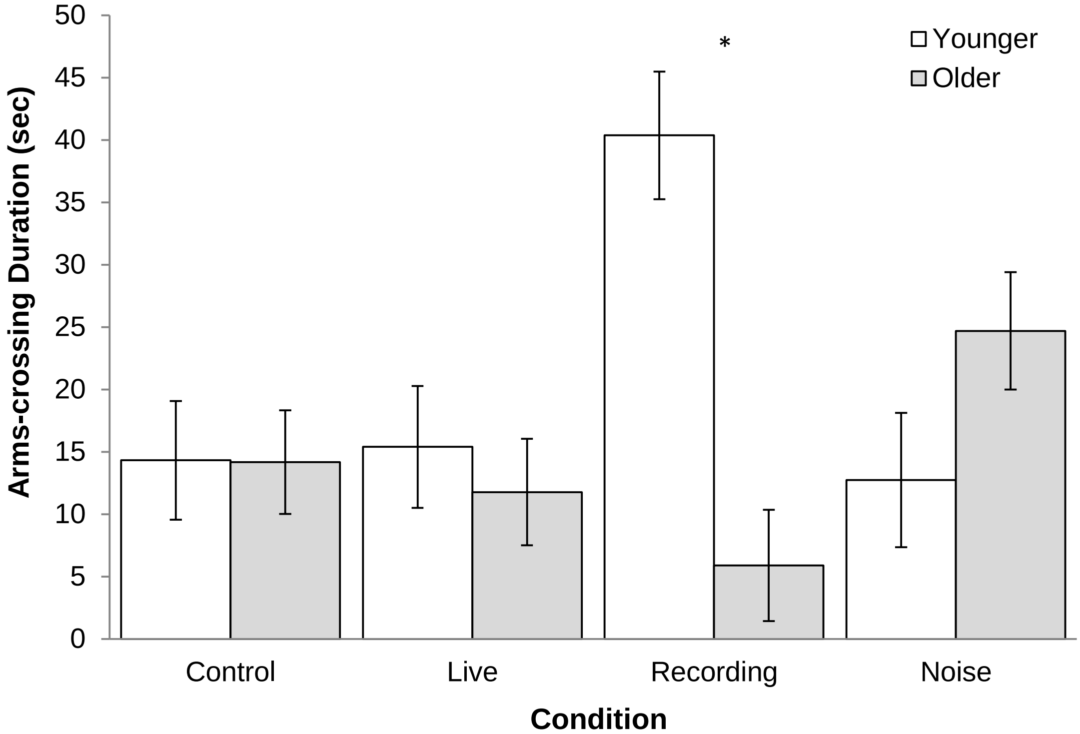

Figure 2.111. Average ‘Arms-crossed’ duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

Figure 2.112. Average ‘Arms-crossed’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences in ‘Face press’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicate a significant Condition main effect, F (2.59, 72.56) = 3.11, p = .038, η_p^2 = .10. No main effects of GA F (1, 28) = 0.15 p = .701, η_p^2 = .01, or an interaction F (2.59, 72.56) = 1.10, p = .349, η_p^2 = .04, were found. In support of this polynomial contrasts of Condition indicated a significant linear trend F (1, 28) = 4.42, p = .045, η_p^2 = .14, which is qualified by a significant cubic trend F (1, 28) = 8.11, p = .008, η_p^2 = .23. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.38) to the ‘Noise’ condition (M = 0.94). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.45) than the ‘Live’ condition (M = 0.64) producing the cubic trend.

Post-hoc analysis of the main effect of condition showed a trend between ‘Control’ and ‘Noise’ with a higher ‘Face press’ frequency in ‘Noise’ (M = 0.94) compared to ‘Control’ (M = 0.38, p = .069) (see Figure 2.113). No further effects were found. The means and standard errors can be examined in Table 2.73.

Table 2.73. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.56	0.18	0.65	0.16		
Control	0.53	0.23	0.24	0.20	0.38	0.16
Live	0.46	0.27	0.82	0.23	0.64	0.18
Recording	0.31	0.24	0.59	0.21	0.45	0.16
Noise	0.93	0.29	0.95	0.25	0.94	0.19

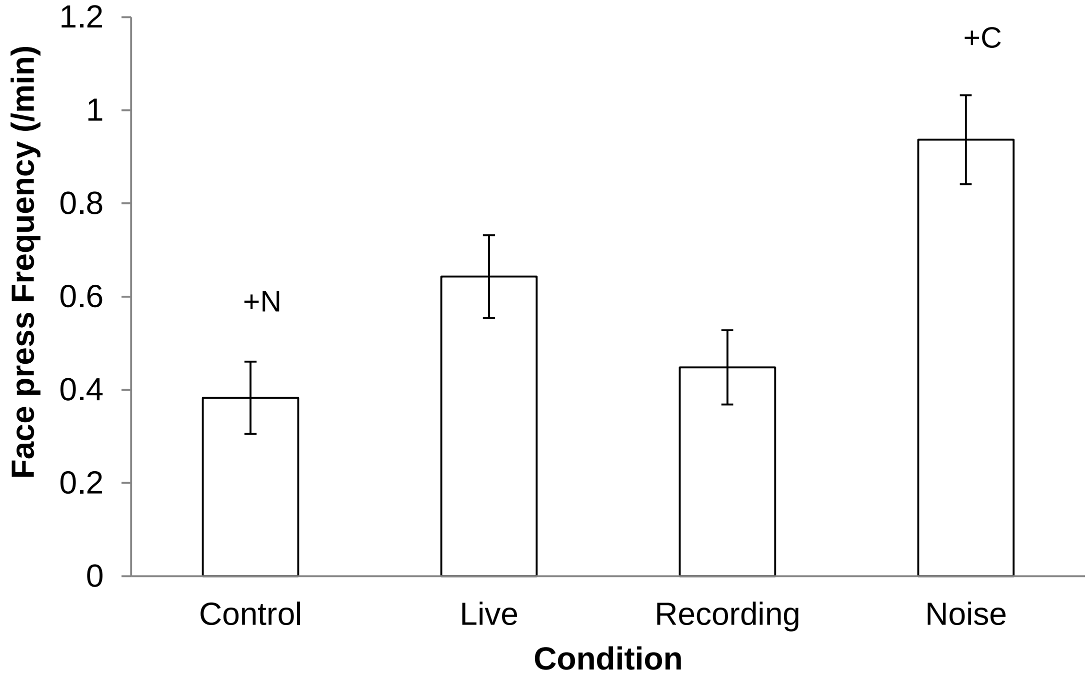

Figure 2.113. Average 'Face press' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

*Mixed-design ANOVA Condition*GA: 'Face press' Duration*

A mixed design ANOVA was conducted to assess differences in 'Face press' duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Huynh-Feldt correction was used. Results show a significant main effect of Condition F (2.56, 71.75) = 3.41, p = .028, η_p^2 = .11. No main effects of GA F (1, 28) = 0.22 p = .647, η_p^2 = .01, or an interaction F (2.56, 71.75) = 0.91, p = .428, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 28) = 5.20, p = .030, η_p^2 = .16, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 28) = 8.68, p = .006, η_p^2 = .24. Overall, there is a linear increase produced by the means from 'Control' (M = 17.42) to the 'Noise' condition (M = 46.60). However, the 'Recording' condition has a somewhat lower mean (M = 22.26) than the 'Live' condition (M = 32.12) producing the cubic trend.

Post-hoc analysis of the main effect of Condition showed a significant difference between 'Control' and 'Noise' with an increased duration of 'Face press' in

‘Noise’ (M = 46.60) compared to ‘Control’ (M = 17.42, *p* = .040) (see Figure 2.114). No further effects were found. The means and standard errors can be examined in Table 2.74.

Table 2.74. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	26.92	8.72	32.28	7.62		
Control	23.07	10.58	11.77	9.25	17.42	7.02
Live	23.08	13.29	41.17	11.62	32.12	8.82
Recording	15.36	11.90	29.16	10.41	22.26	7.91
Noise	46.15	14.32	47.04	12.52	46.60	9.51

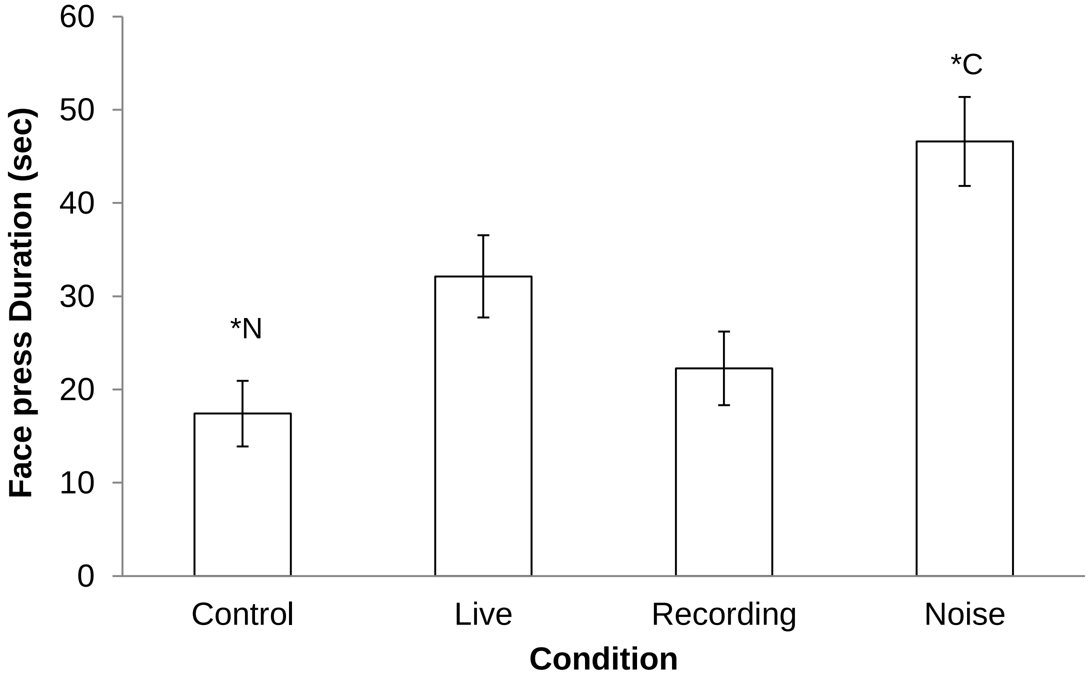

Figure 2.114. Average ‘Face press’ duration (in seconds) including standard errors for each condition (*< .05).

90-120 Interval analysis combined

*Mixed-design ANOVA Condition*GA: 'General Movement' Frequency*

A mixed design ANOVA was conducted to assess differences in 'General movement' frequency and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effect of Condition F (3, 84) = 0.14, p = .935, η_p^2 = .01, and interaction between Condition and GA, F (3, 84) = 1.19, p = .318, η_p^2 = .04. However, a significant main effect of GA F (1, 28) = 22.12, p < .001, η_p^2 = .44, was found.

Post-hoc analysis of the main effect of GA showed a significant difference between younger and older fetuses with younger fetuses (M = 7.22) displaying increased 'General movement' frequencies compared to older fetuses (M = 3.12, p < .001) (see Figure 2.115). No further effects were found. The means and standard errors can be examined in Table 2.75.

Table 2.75. Means and standard errors (SE) of fetuses 'General movement' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.22	0.66	3.12	0.57		
Control	6.23	1.37	3.06	1.19	4.65	0.91
Live	6.01	1.41	4.72	1.24	5.36	0.94
Recording	8.33	1.25	2.83	1.09	5.58	0.83
Noise	8.32	2.00	1.88	1.75	5.10	1.33

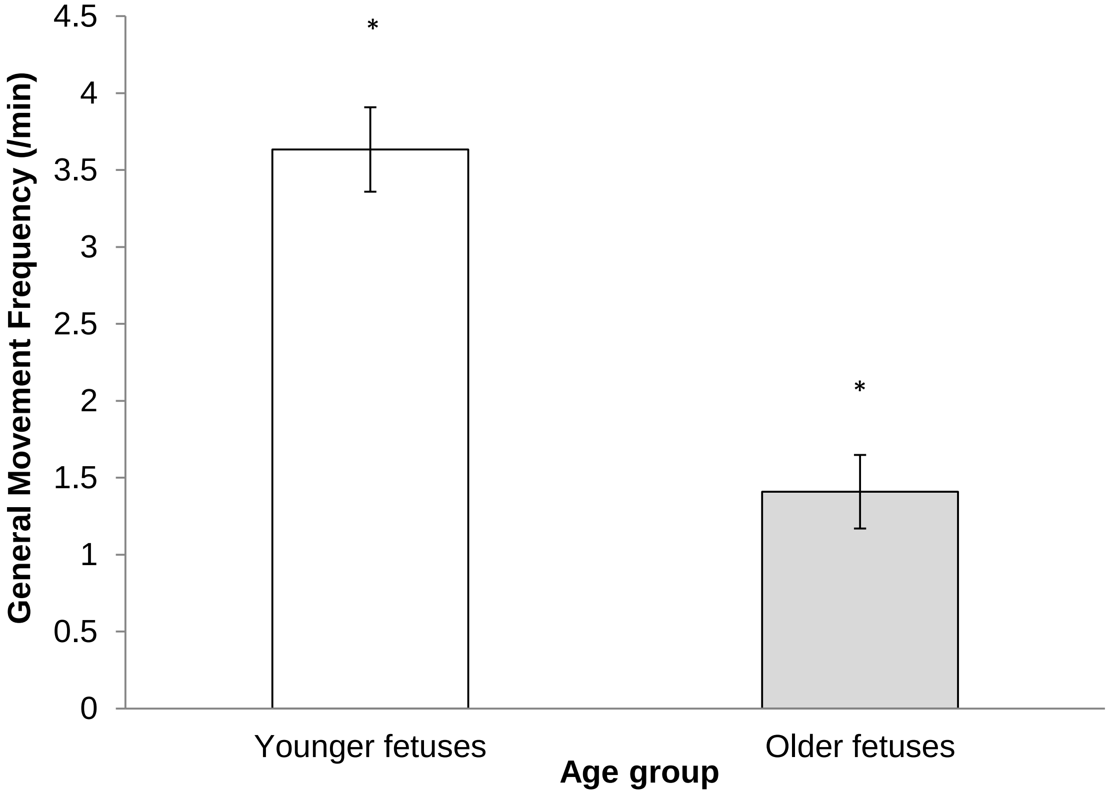

Figure 2.115. Average ‘General movement’ frequency (per minute) including standard errors for GA (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘General Movement’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘General movement’ duration and GA across the four Conditions (Control, Live, Recording, Noise).

Results showed no significant main effect of Condition F (3, 84) = 0.27, p = .845, η_p^2 = .01, and interaction between Condition and GA, F (3, 84) = 0.37, p = .773, η_p^2 = .01. However, a significant main effect of GA F (1, 28) = 9.35, p = .005, η_p^2 = .25, was found.

Post-hoc analysis of the main effect of GA showed a significant difference between younger and older fetuses with younger fetuses (M = 3.63) displaying longer ‘General movement’ durations compared to older fetuses (M = 1.41, p = .005) (see Figure 2.116). No further effects were found. The means and standard errors can be examined in Table 2.76.

Table 2.76. Means and standard errors (SE) of fetuses 'General movement' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.63	0.55	1.41	0.48		
Control	3.18	1.01	1.17	0.88	2.17	0.67
Live	3.97	0.79	0.54	0.69	2.25	0.53
Recording	3.81	1.06	1.86	0.93	2.84	0.70
Noise	3.58	1.27	2.06	1.11	2.82	0.84

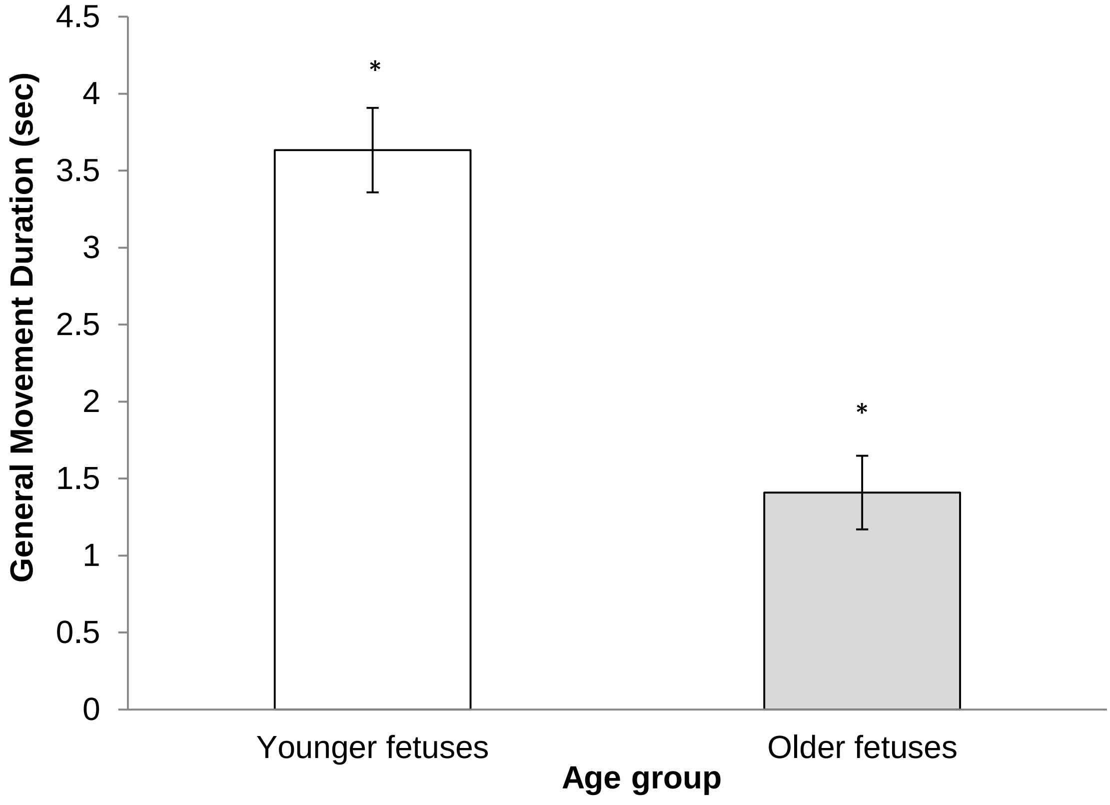

Figure 2.116. Average 'General movement' duration (in seconds) including standard errors for GA (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: 'Inactivity/Resting' Frequency*

A mixed design ANOVA was conducted, using Huynh-Feldt correction, to assess differences in 'Inactivity/Resting' frequency and GA across the four

Conditions (Control, Live, Recording, Noise). Results showed no significant main effect of Condition F (2.678, 74.991) = 2.08, p = .117, η_p^2 = .07, or main effect of GA F (1, 28) = 1.02, p = .320, η_p^2 = .04. However, a significant interaction between Condition and GA, F (2.678, 74.991) = 2.91, p = .046, η_p^2 = .09, was found. In support of this polynomial contrasts of the interaction indicated a significant cubic trend F (1, 28) = 4.55, p = .042, η_p^2 = .14. Post-hoc analysis of the interaction revealed a significant difference in ‘Recording’ between age groups, with younger fetuses (M = 1.70) displaying more ‘Inactivity/Resting’ compared to older fetuses (M =0.35, p = .032). Furthermore, marginally significant results were found for younger fetuses between ‘Control’ and ‘Recording’, with more ‘Inactivity/Resting’ during ‘Recording’ (M = 1.70) compared to ‘Control’ (M = 0.46, p = 0.69). And younger fetuses showed marginally significant differences in ‘Inactivity/Resting’ between ‘Live’ and ‘Recording’, with increased ‘Inactivity/Resting’ in ‘Recording’ (M = 1.70) compared to ‘Live’ (M = 0.46, p = 0.60) (see Figures 2.117 and 2.118). No further effects were found. The means and standard errors can be examined in Table 2.77.

Table 2.77. Means and standard errors (SE) of fetuses ‘Inactivity/Resting’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.89	0.18	0.65	0.16		
Control	0.46	0.25	0.59	0.22	0.53	0.17
Live	0.46	0.24	0.47	0.21	0.47	0.16
Recording	1.70	0.45	0.35	0.39	1.02	0.30
Noise	0.93	0.35	1.18	0.31	1.05	0.24

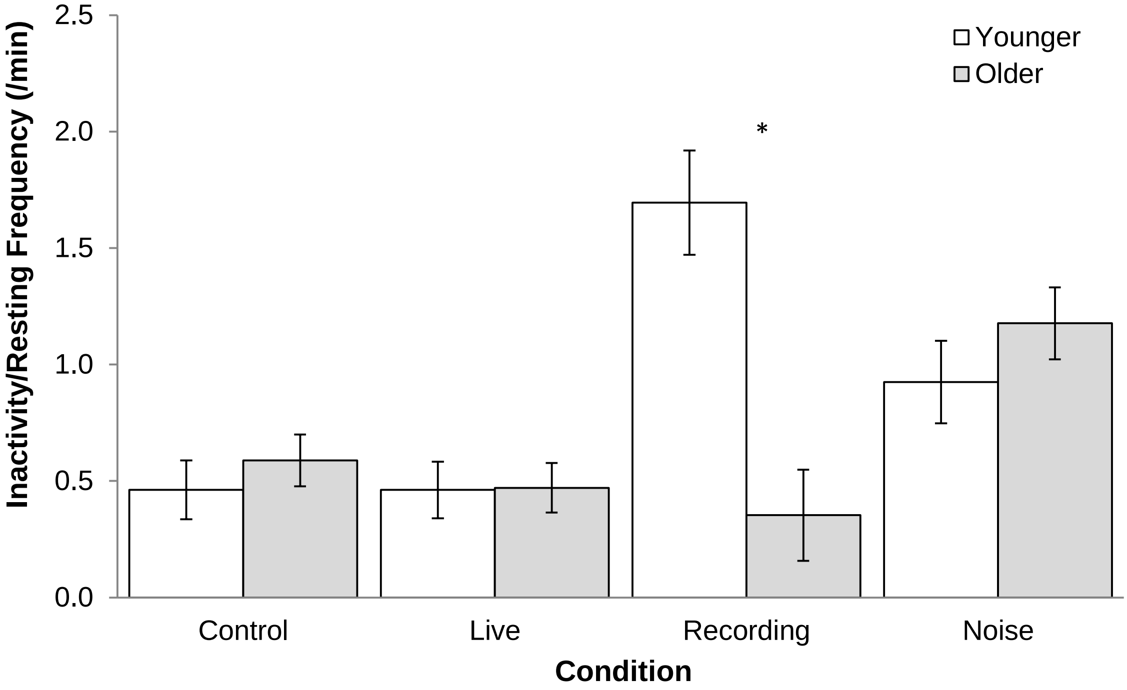

Figure 2.117. Average ‘Inactivity/Resting’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

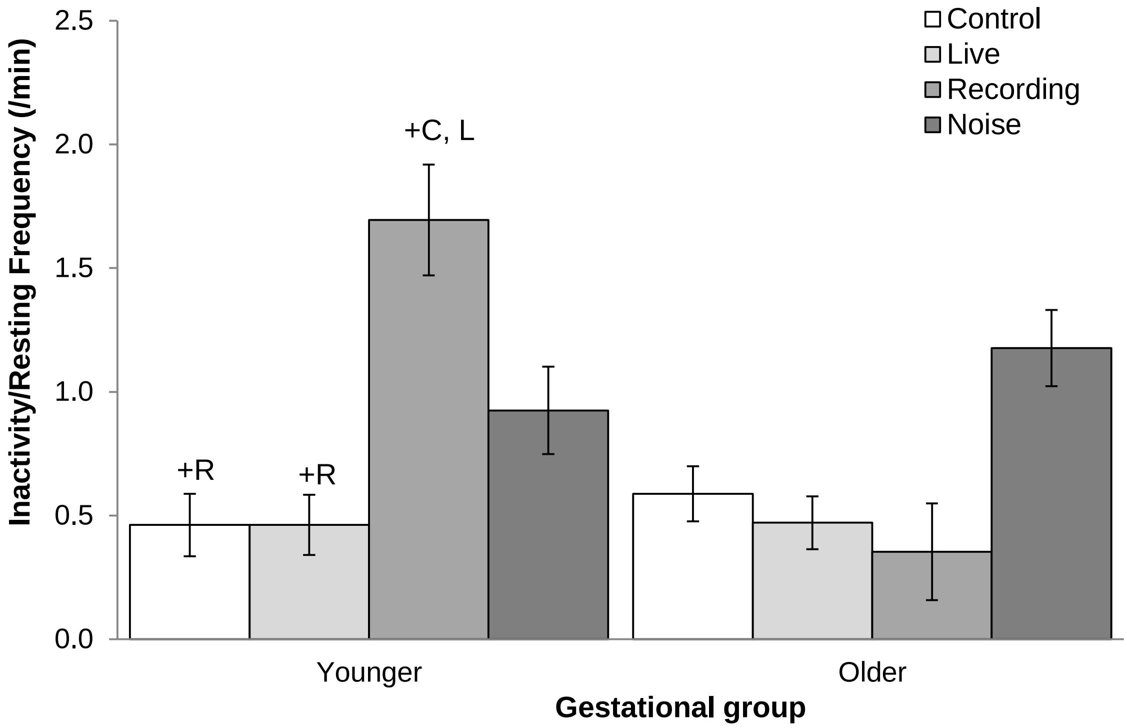

Figure 2.118. Average ‘Inactivity/Resting’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

0-120 Interval analysis

Repeated-measures ANOVA Condition: 'Face press' Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the 'Face press' between the four Conditions (Control, Live, Recording, Noise). As the assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. Results indicate a tendency between the Conditions F (2.18, 60.98) = 2.33, p = .032, η_p^2 = .08. Examination of these means suggests that fetuses 'Face press' frequency changed depending on Condition. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 28) = 4.43, p = .044, η_p^2 = .14. However, this finding was qualified by the significant cubic trend, F (1, 28) = 5.48, p = .027, η_p^2 = .16. Overall, there is a linear increase produced by the means from 'Control' (M = 0.09) to the 'Noise' condition (M = 0.22). However, the 'Recording' condition has a somewhat lower mean (M = 0.12) than the 'Live' condition (M = 0.19) producing the cubic trend.

Post-hoc analysis showed a trend towards a difference between 'Noise' (M = 0.22) and 'Control' (M = 0.09, p = .0.58), with fetuses increasing 'Face press' frequency in the 'Noise' condition compared to 'Control' (see Figure 2.119). No further effects were found. The means and standard errors can be examined in Table 2.78.

Table 2.78. Means and standard errors (SE) on the duration of fetuses 'Face press' of the uterus across conditions.

	Control	Live	Recording	Noise
Mean	0.09	0.19	0.12	0.22
SE	0.4	0.6	0.04	0.05

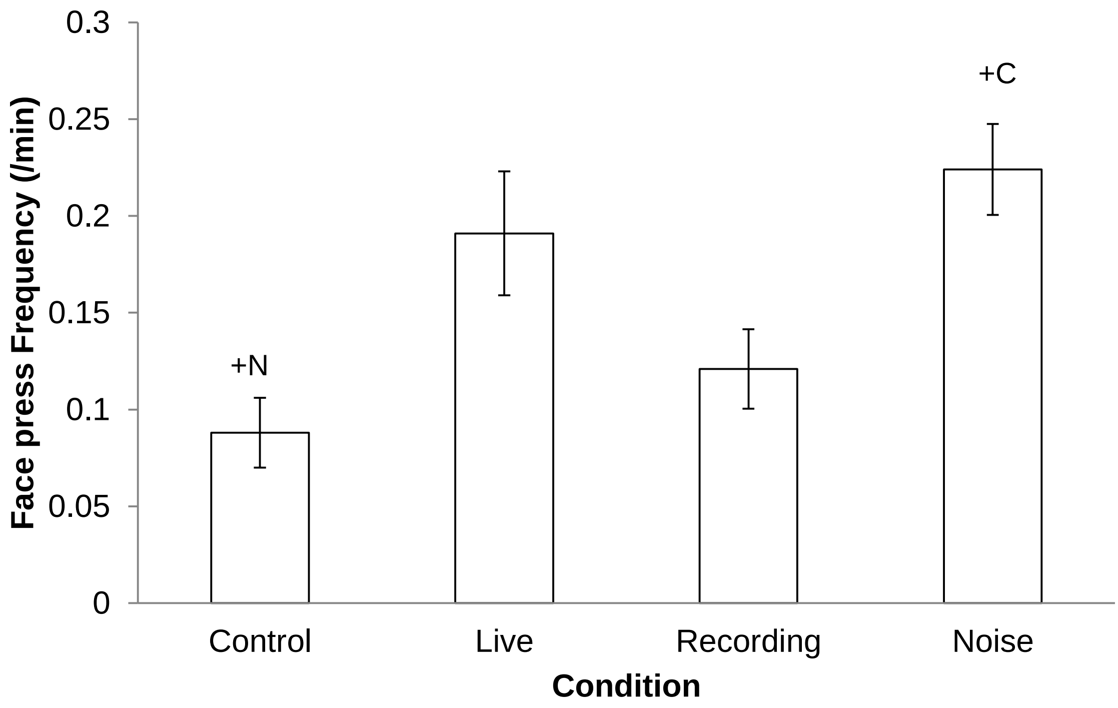

Figure 2.119. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA, with Greenhouse-Geisser correction, was conducted to assess whether there are differences in duration of the ‘Face press’ between the four Conditions (Control, Live, Recording, Noise). Results indicate that there was a significant difference in ‘Face press’ duration between the four Conditions F (2.17, 60.79) = 3.25, p = .026, η_p^2 = .10. Examination of these means suggests that ‘Face press’ duration differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant linear trend, F (1, 28) = 6.16, p = .019, η_p^2 = .18. However, this finding was qualified by the significant cubic trend, F (1, 28) = 7.703, p = .010, η_p^2 = .22. Overall, there is a linear increase produced by the means from ‘Control’ (M = 15.19) to the ‘Noise’ condition (M = 44.83). However, the ‘Recording’ condition has a somewhat lower mean (M = 24.14) than the ‘Live’ condition (M = 30.72) producing the cubic trend.

Post-hoc analysis revealed a significant difference between ‘Noise’ and ‘Control’, with fetuses increasing ‘Face press’ duration in the ‘Noise’ (M = 44.83) condition compared to ‘Control’ (M = 15.19, p = .032) (see Figure 2.120). No further effects were found. The means and standard errors can be examined in Table 2.79.

Table 2.79. Means and standard errors (SE) on the duration of ‘Face press’ against the uterus across conditions.

	Control	Live	Recording	Noise
Mean	15.19	30.72	24.14	44.83
SE	6.56	8.66	8.09	9.40

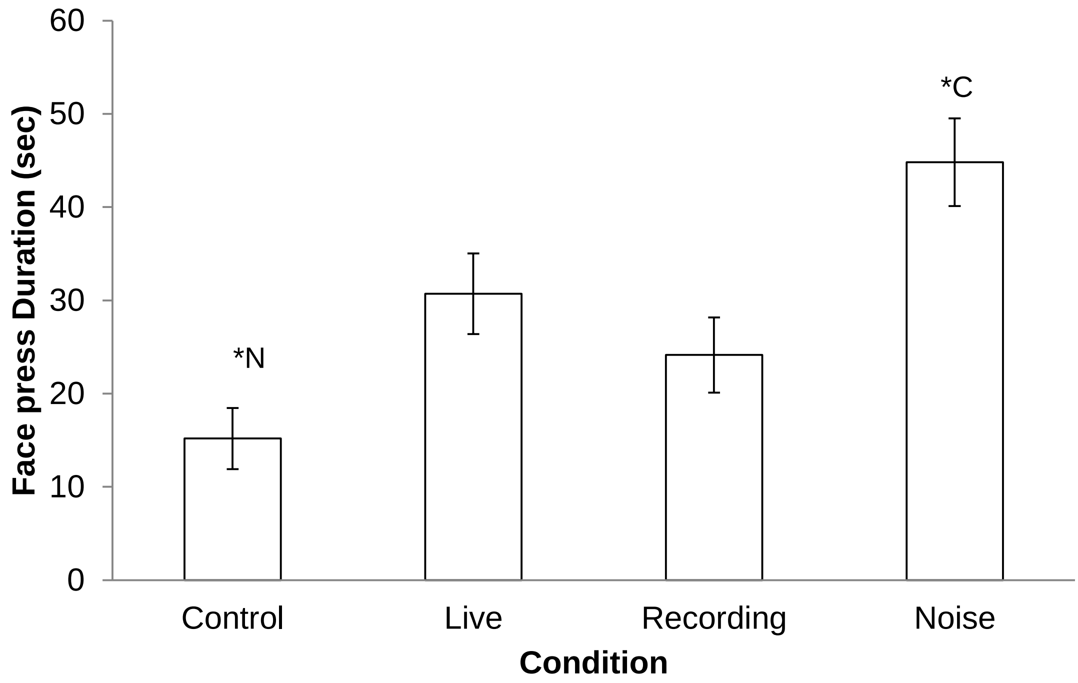

Figure 2.120. Average ‘Face press’ duration (in seconds) including standard errors for each condition (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Arm Movement’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Arm movement’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results showed no significant main effects of Condition F (3, 81) = 0.82, p = .489, η_p^2 = .03, but the interaction showed a tendency F (3, 81) = 2.34, p = .080, η_p^2 = .08 and GA showed a significant main effect F (1, 27) =

7.086, p = .013, η_p^2 = .21. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 27) = 8.69, p = .007, η_p^2 = .24.

Post-hoc analysis of the interaction showed no further significant differences or trends. Post-hoc analysis of the main effect of GA showed that younger fetuses (M = 3.51) moved their arms more frequently compared to older fetuses (M = 3.51, p = .013) (see Figure 2.123). Younger fetuses move their arms significantly more in 'Live' (M = 4.58) compared to 'Noise' (M = 2.27, p = .007) (see Figures 2.121 and 2.122). No further effects were found. The means and standard errors can be examined in Table 2.80.

Table 2.80. Means and standard errors (SE) of fetuses 'Arm movement' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.51	0.33	2.32	0.30		
Control	3.30	0.73	2.63	0.66	2.96	0.49
Live	4.58	0.67	1.78	0.60	3.18	0.45
Recording	3.88	0.61	2.41	0.55	3.15	0.41
Noise	2.27	0.49	2.47	0.44	2.37	0.33

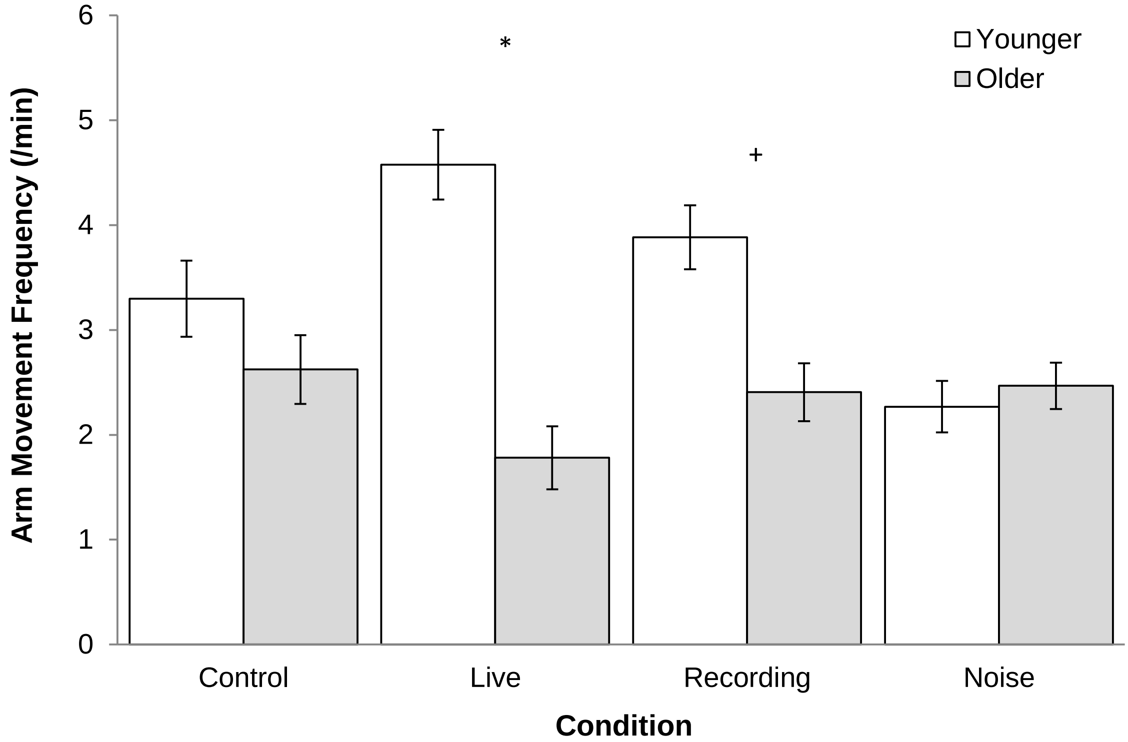

Figure 2.121. Average ‘Arm movement’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

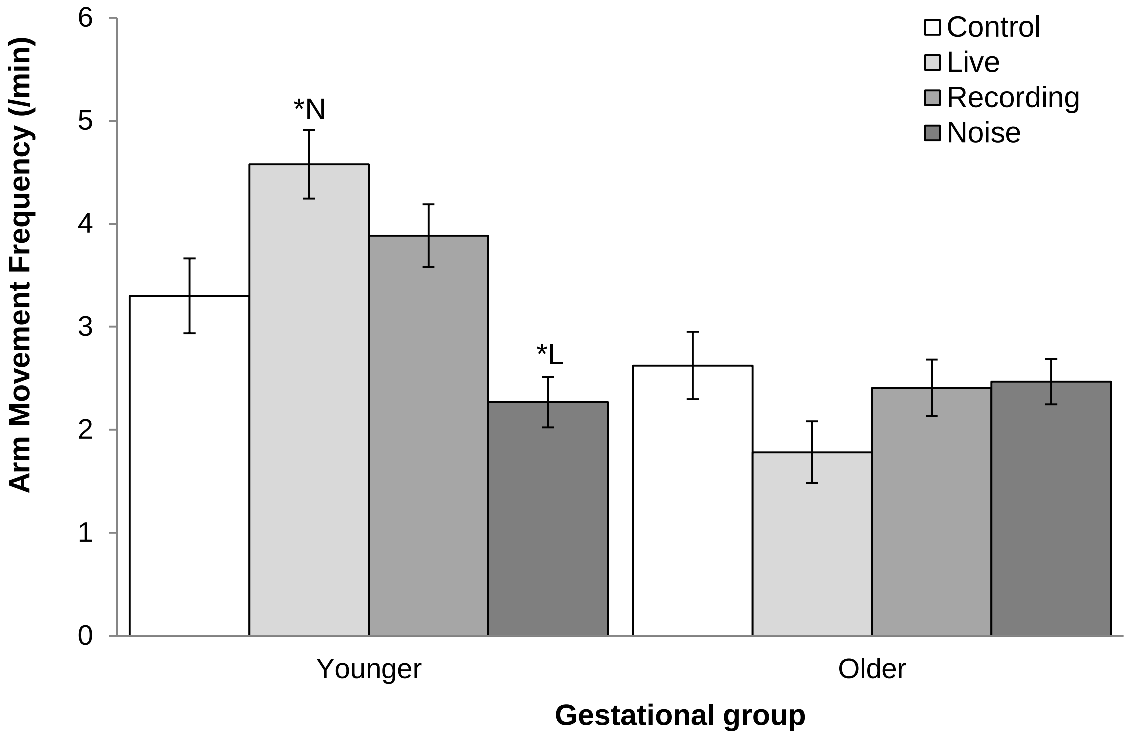

Figure 2.122. Average ‘Arm movement’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

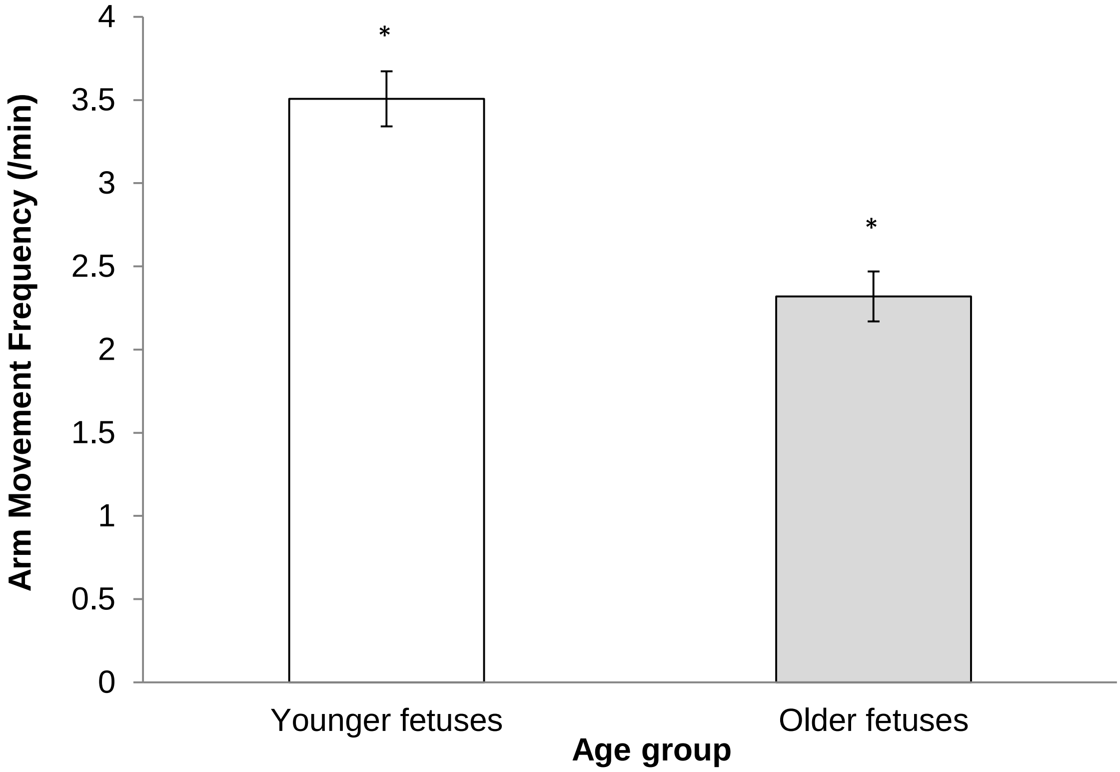

Figure 2.123. Average ‘Arm movement’ frequency (per minute) including standard errors for GA (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Arm Movement’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘Arm movement’ duration and GA across the four Conditions (Control, Live, Recording, Noise). Results showed no significant main effects of Condition F (3, 81) = 1.47, p = .230, η_p^2 = .05, but the interaction showed a tendency F (3, 81) = 2.59, p = .058, η_p^2 = .09, and no significant main effect of GA F (1, 27) = 1.19, p = .284, η_p^2 = .04. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 27) = 5.79, p = .023, η_p^2 = .18. Post-hoc analysis of the interaction showed a significant difference between younger and older fetuses (M = 6.60) in the ‘Live’ condition, with younger fetuses moving their arms longer (M = 21.01, p = 001) (see Figures 2.124 and 2.125). No further effects were found. The means and standard errors can be examined in Table 2.81.

Table 2.81. Means and standard errors (SE) of fetuses ‘Arm movement’ duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	19.26	3.44	14.20	3.10		
Control	16.83	5.62	17.70	5.06	17.26	3.78
Live	21.01	2.98	6.60	2.68	13.81	2.00
Recording	27.58	5.76	15.66	5.19	21.62	3.88
Noise	11.62	5.69	16.85	5.13	14.24	3.83

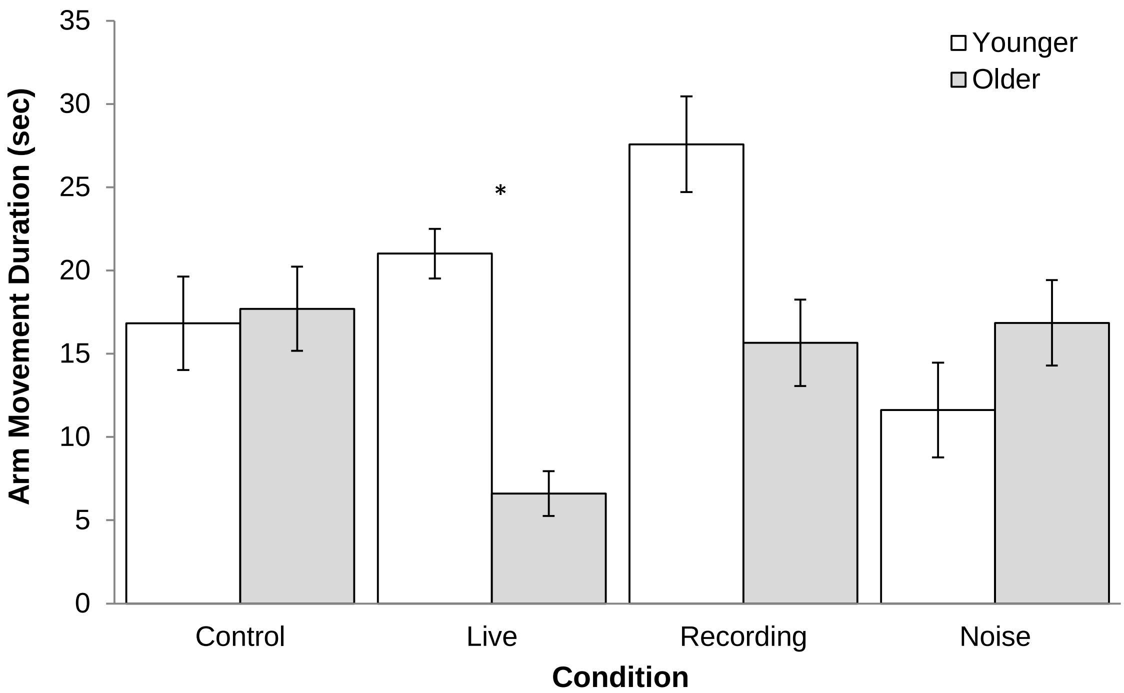

Figure 2.124. Average ‘Arm movement’ duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (*< .05).

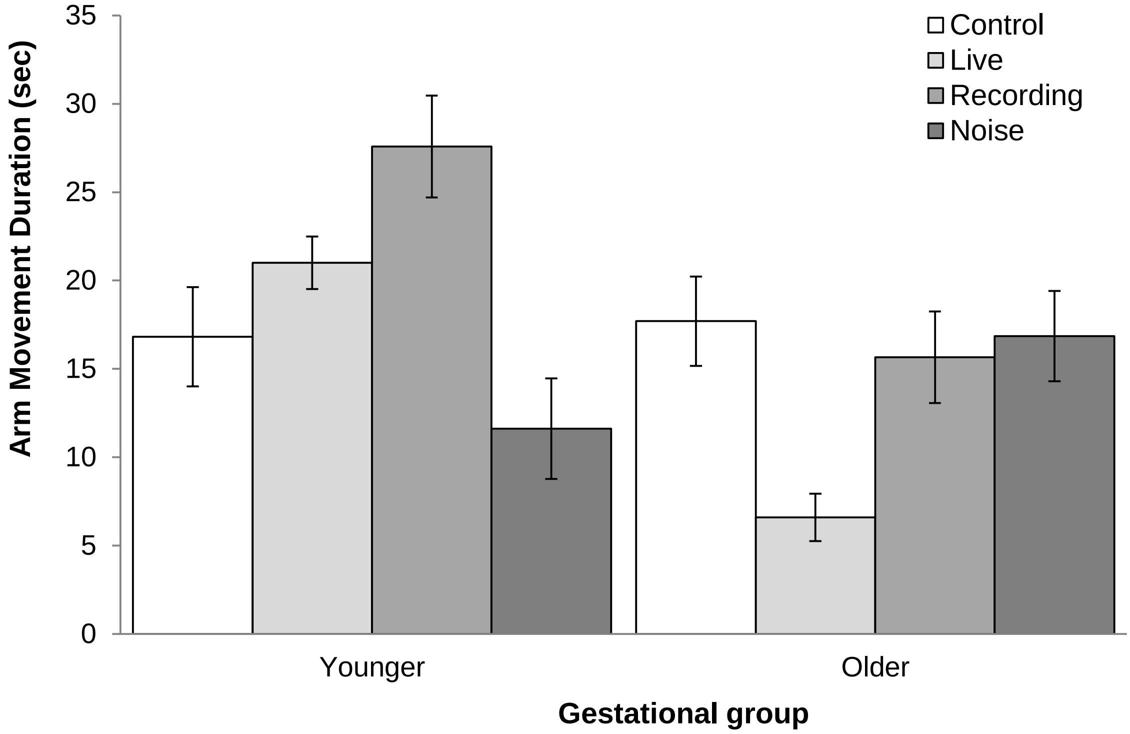

Figure 2.125. Average ‘Arm movement’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: ‘Body Touch’ Frequency*

A mixed design ANOVA was conducted to assess differences in ‘Body touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. Results showed a tendency for an interaction between Condition and GA, F (1.94, 52.28) = 2.47, p = .096, η_p^2 = .08. No main effects of Condition F (1.94, 52.28) = 0.79, p = .454, η_p^2 = .03, or GA F (1, 27) = 0.14, p = .709, η_p^2 = .01, were found. In support of this polynomial contrasts of the interaction indicated a significant cubic trend F (1, 27) = 4.55, p = .042, η_p^2 = .14. Post-hoc analysis of the interaction showed no further significant results or tendencies (see Figures 2.126 and 2.127). No further effects were found. The means and standard errors can be examined in Table 2.82.

Table 2.82. Means and standard errors (SE) of fetuses 'Body touch' frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.34	0.12	0.40	0.11		
Control	0.23	0.15	0.25	0.14	0.24	0.10
Live	0.35	0.14	0.19	0.12	0.27	0.09
Recording	0.62	0.22	0.25	0.20	0.43	0.15
Noise	0.15	0.36	0.91	0.32	0.53	0.24

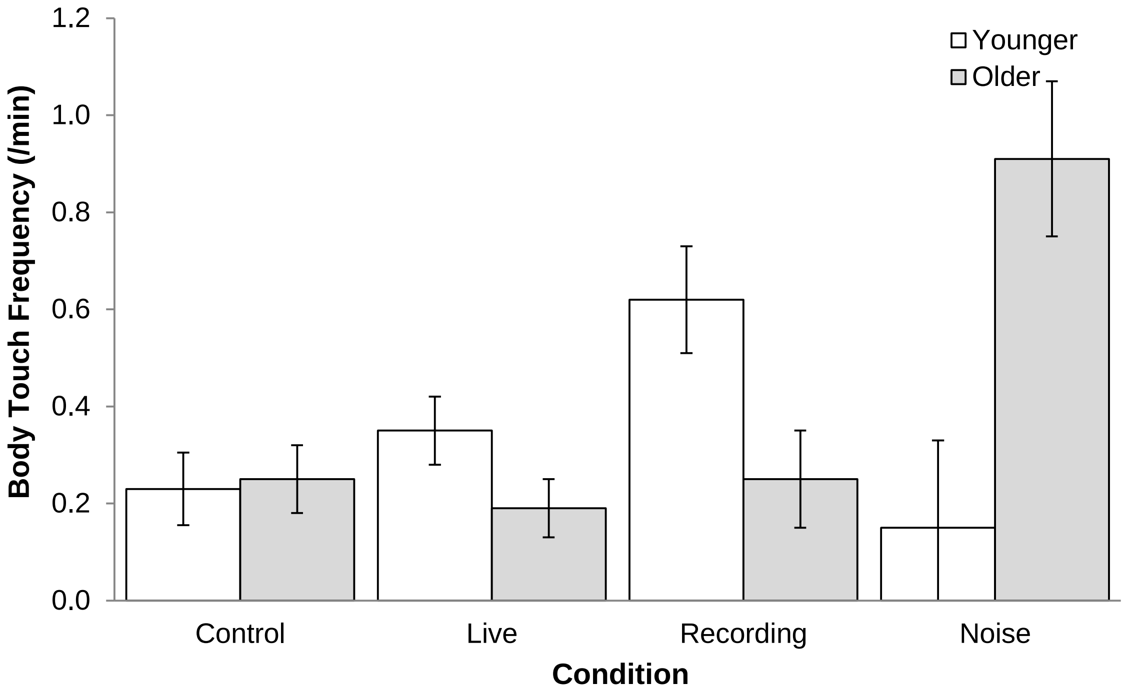

Figure 2.126. Average 'Body touch' frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses).

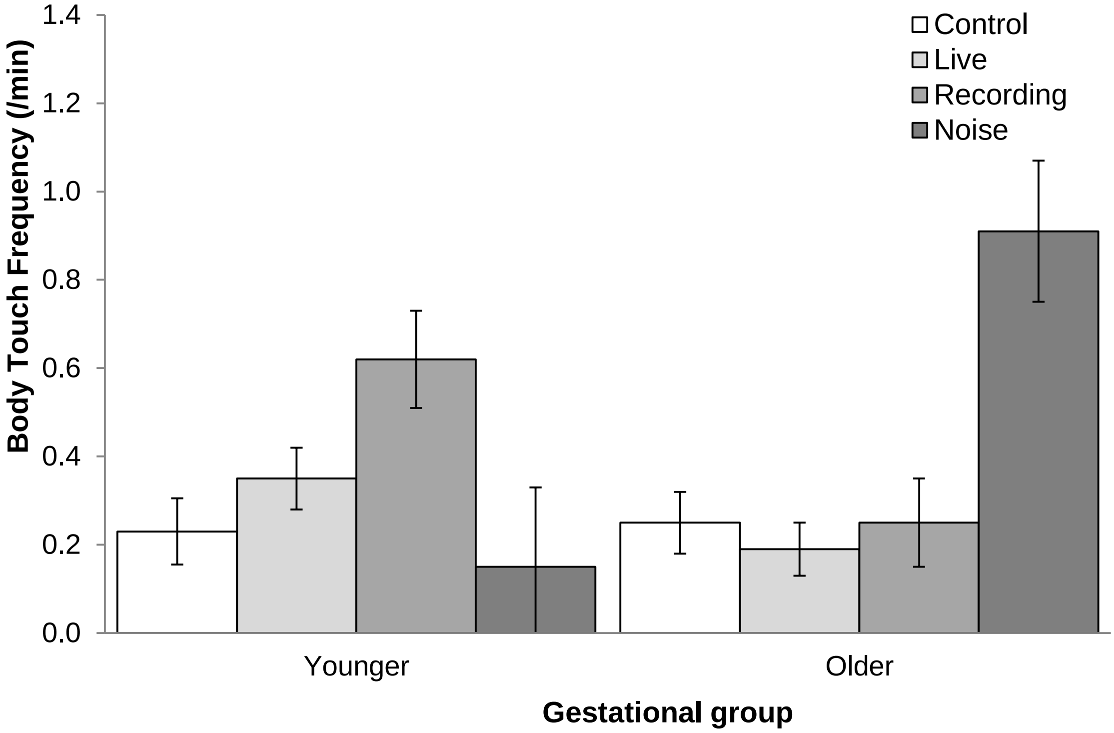

Figure 2.127. Average ‘Body touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: ‘Uterus Touch’ Frequency*

A mixed ANOVA was conducted to assess differences in ‘Uterus touch’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). Results indicated a significant interaction between Condition and GA, F (3, 81) = 4.00, p = .011, η_p^2 = .13. No main effects of Condition F (3, 81) = 0.59, p = .624, η_p^2 = .02, or GA F (1, 27) = 1.95, p = .174, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 27) = 4.92, p = .035, η_p^2 = .15 of Condition and GA. This finding is qualified by the significant cubic trend of Condition and GA F (1, 27) = 6.26, p = .019, η_p^2 = .19. Post-hoc analysis of the interaction showed that younger fetuses (M = 1.08) touched the uterus significantly more in ‘Live’ compared to older fetuses (M = 0.06, p = .011). A further tendency was observed between age groups in ‘Noise’, with older fetuses (M = 0.69) touching the uterus more frequently compared to younger fetuses (M = 0.08, p = .099) (see Figures 2.128 and

2.129). No further effects were found. The means and standard errors can be examined in Table 2.83.

Table 2.83. Means and standard errors (SE) of fetuses ‘Uterus touch’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.54	0.11	0.34	0.10		
Control	0.39	0.17	0.19	0.16	0.29	0.12
Live	1.08	0.28	0.63	0.25	0.57	0.19
Recording	0.62	0.23	0.41	0.21	0.51	0.15
Noise	0.08	0.27	0.69	0.24	0.38	0.18

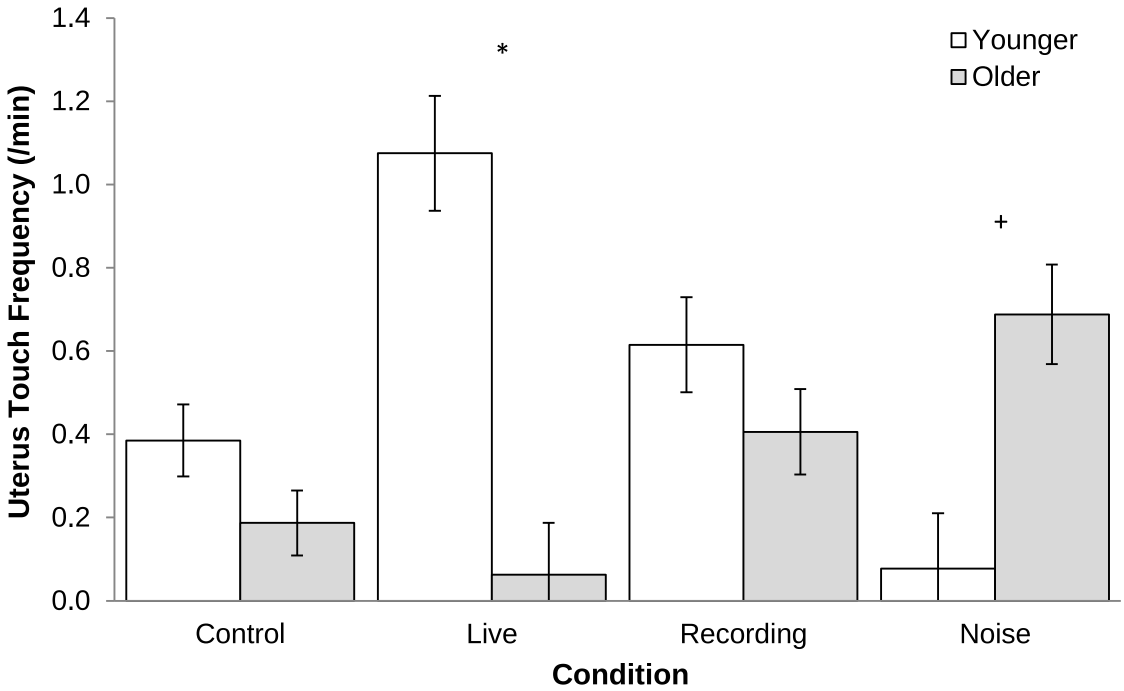

Figure 2.128. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four Conditions across GA (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

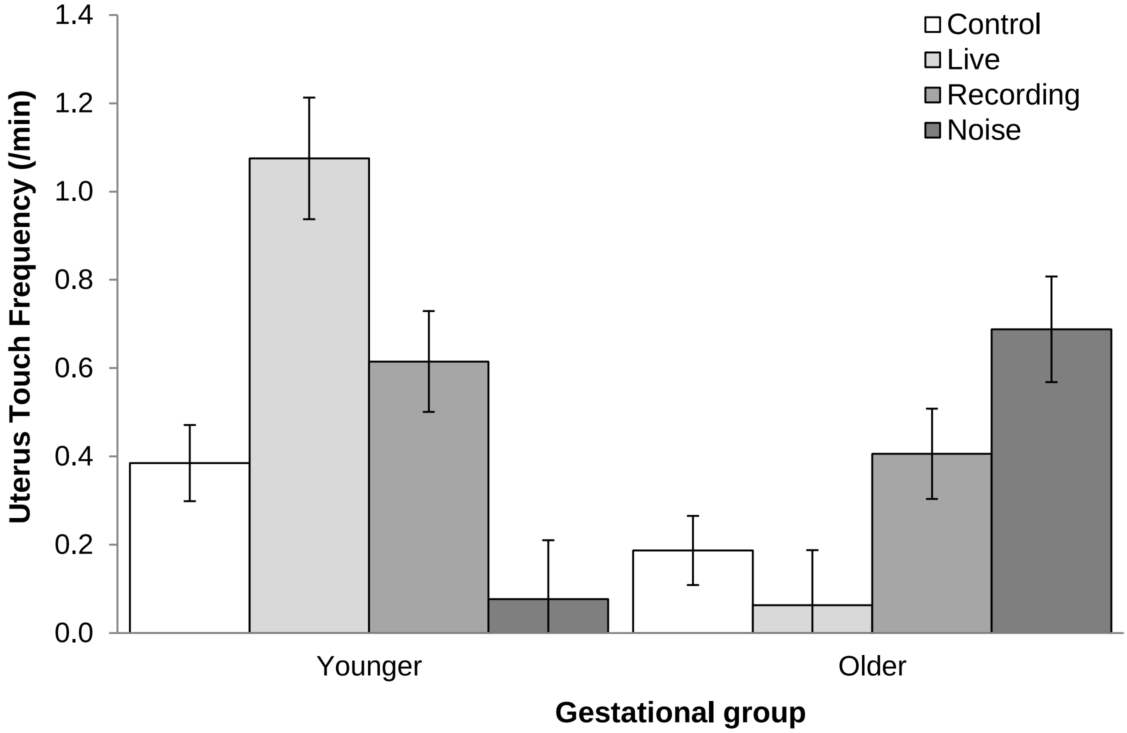

Figure 2.129. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses).

*Mixed-design ANOVA Condition*GA: ‘Uterus Touch’ Duration*

A mixed ANOVA was conducted to assess differences in ‘Uterus touch’ duration and GA across the four Conditions (Control, Live, Recording, Noise). No significant main effect of Condition F (3, 81) = 1.88, p = .140, η_p^2 = .07 but a trend for GA F (1, 27) = 3.83, p = .061, η_p^2 = .12 was found. Results showed the interaction between Condition and GA revealed a tendency, F (3, 81) = 2.83, p = .056, η_p^2 = .09. In support of this polynomial contrasts indicated a linear trend F (1, 27) = 4.60, p = .041, η_p^2 = .15 of Condition and GA.

Post-hoc analysis of the interaction showed that younger fetuses (M = 39.02) touched the uterus significantly longer in ‘Live’ compared to older fetuses (M = 5.59, p = .008). Younger fetuses increased ‘Uterus touch’ duration significantly in ‘Live’ (M = 39.02) compared to ‘Noise’ (M = 5.52, p = .021) (see Figures 2.130 and 2.131). No further effects were found. The means and standard errors can be examined in Table 2.84.

Table 2.84. Means and standard errors (SE) of fetuses 'Uterus touch' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	23.42	4.88	10.55	4.40		
Control	20.11	7.62	3.25	6.87	11.68	5.13
Live	39.02	8.71	5.69	7.85	22.35	5.86
Recording	29.04	10.27	19.29	9.25	24.16	6.91
Noise	5.52	6.75	13.98	6.09	9.75	4.55

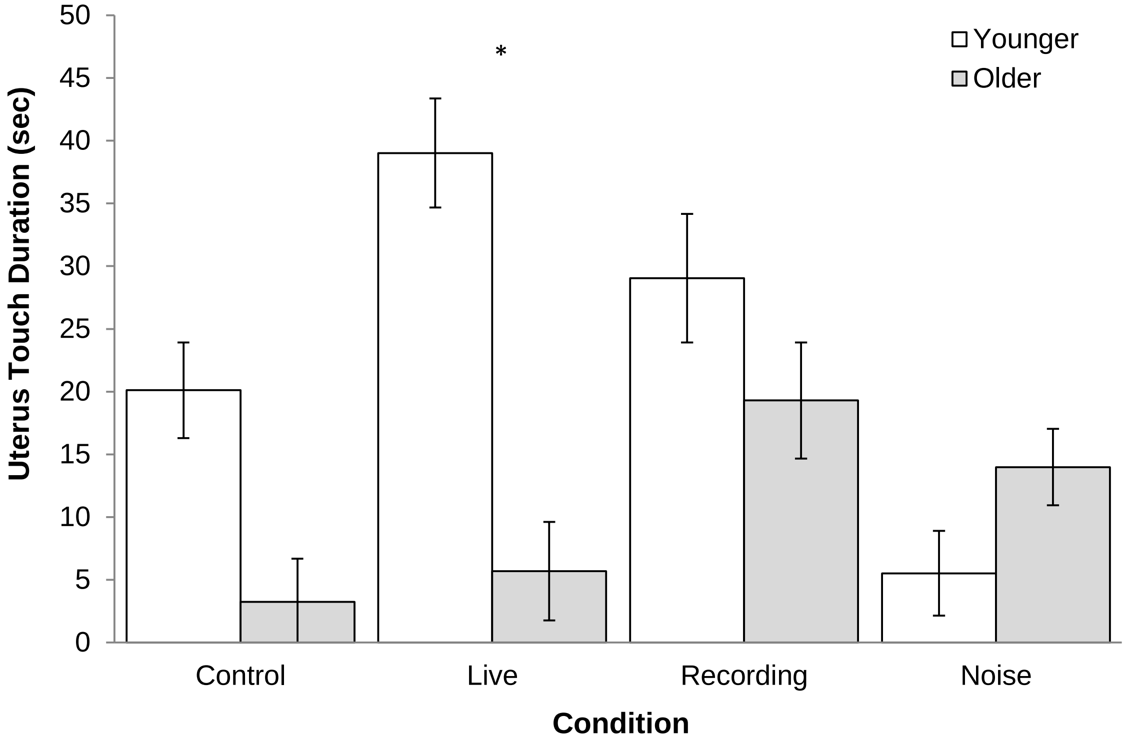

Figure 2.130. Average 'Uterus touch' duration (in seconds) including standard errors for all four Conditions across GA (younger and older fetuses) (*< .05).

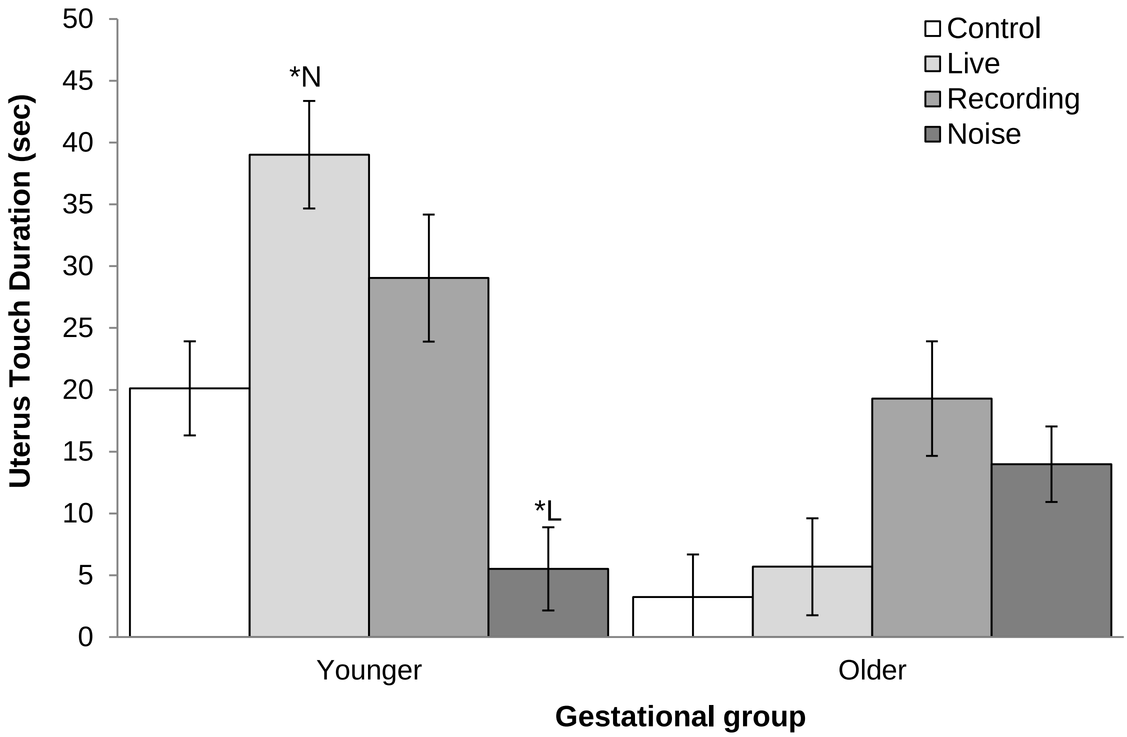

Figure 2.131. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

*Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency*

A mixed design ANOVA was conducted, using Greenhouse-Geisser correction, to assess differences in ‘Face press’ frequency and GA across the four Conditions (Control, Live, Recording, Noise). The Condition main effect was not significant, F (2.19, 59.18) = 2.21, p = .114, η_p^2 = .08. No main effects of GA F (1, 27) = 0.09, p = .765, η_p^2 < .001, or an interaction F (2.19, 59.18) = 2.00, p = .140, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 27) = 4.96, p = .034, η_p^2 = .16 of Condition. Overall, there is a linear increase produced by the means from ‘Control’ (M = 0.09) to the ‘Noise’ condition (M = 0.23). However, the ‘Recording’ condition has a somewhat lower mean (M = 0.12) than the ‘Live’ condition (M = 0.18) producing the cubic trend.

No further effects were found. The means and standard errors can be examined in Table 2.85.

Table 2.85. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.15	0.05	0.17	0.04		
Control	0.16	0.05	0.03	0.05	0.09	0.04
Live	0.12	0.10	0.25	0.09	0.18	0.06
Recording	0.08	0.06	0.16	0.06	0.12	0.04
Noise	0.23	0.07	0.22	0.07	0.23	0.05

*Mixed-design ANOVA Condition*GA: ‘Face press’ Duration*

A mixed design ANOVA was conducted to assess differences in ‘Face press’ duration and GA across the four Conditions (Control, Live, Recording, Noise). The assumption of sphericity was violated, thus Greenhouse-Geisser correction was used. Results show a significant main effect of Condition F (2.12, 57.15) = 3.15, p = .029, η_p^2 = .11. No main effects of GA F (1, 27) = 0.04 p = .853, η_p^2 < .001, or an interaction F (2.12, 57.15) = 1.51, p = .228, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 27) = 5.62, p = .025, η_p^2 = .17, of Condition. This finding is qualified by the significant cubic trend of Condition, F (1, 27) = 7.16, p = .013, η_p^2 = .21. Overall, there is a linear increase produced by the means from ‘Control’ (M = 16.22) to the ‘Noise’ condition (M = 44.95). However, the ‘Recording’ condition has a somewhat lower mean (M = 23.32) than the ‘Live’ condition (M = 29.93) producing the cubic trend.

Post-hoc analysis of the main effect of Condition revealed a significant difference between ‘Control’ and ‘Noise’ with a longer duration of ‘Face press’ in ‘Noise’ (M = 44.95) compared to ‘Control’ (M = 16.22, p = .044) (see Figure 2.132). No further effects were found. The means and standard errors can be examined in Table 2.86.

Table 2.86. Means and standard errors (SE) of fetuses 'Face press' duration across conditions and GA as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	27.52	8.59	29.69	7.75		
Control	26.18	9.56	6.25	8.62	16.22	6.44
Live	22.37	12.99	37.50	11.71	29.93	8.75
Recording	15.29	12.09	31.25	10.90	23.32	8.14
Noise	46.15	14.29	43.75	12.88	44.95	9.62

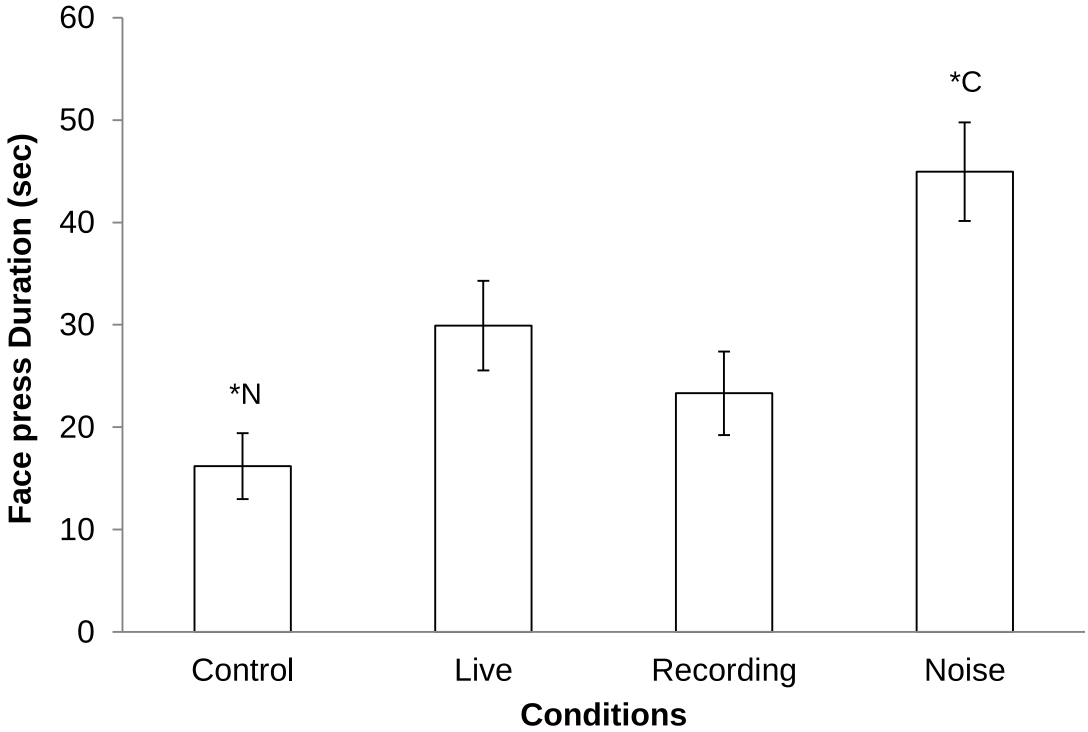

Figure 2.132. Average 'Face press' duration (in seconds) including standard errors for each condition (*< .05).

Discussion

Overall the aim of Experiment 1 was to examine fetal responses to differential auditory stimuli. More particularly, to examine whether fetuses discriminate between maternal voice presentations of either live or recorded voice. This aim was explored by comparing maternal voice (recorded and live) to common, inanimate stimulation as well as to a silent, control condition in order to eliminate that the observed responses are purely based on an auditory response rather than to the properties of the maternal voice. The differentiation between social and non-social stimuli was explored and gestational groups were designed to examine these differences between second- and third-trimester fetuses. Lastly, the aim of Experiment 1 was to include examining how these responses might change over the time of stimulation.

Aim 1: Differentiation between Live and Recorded Maternal Voice

Hypothesis 1 predicted that fetuses react differently to mother's live voice compared to her recorded voice, with a preferential response to the live voice over the recorded stimuli. Furthermore, it was predicted that fetuses would show a stronger response to mother's live voice than recorded voice, compared to control.

Results showed that, in second-trimester fetuses, responses to mother's live voice elicit a much stronger arousal response from the fetus, compared to recorded voice. Although both variables display an indifferent amount of arousal at times, for example, 'Arm movement' frequency and duration measures and patterns are almost identical although the fetus moves ever so slightly more in response to live voice for the most part of the stimulation. Later on, however, younger fetuses increase their 'Arm movements' significantly during live compared to the everyday noise condition, whereas differences between the recorded voice and everyday noise appear slightly weaker, indicating only a tendency between the two. On the other hand, responses to the recorded voice are often comparable to the responses in the control condition. Further differences can be observed between younger and older fetuses' reaction to the two voice conditions. Older fetuses appear to react less; with a decrease in 'Arm movement' frequencies and durations to the mother's voices, whereas younger fetuses experience an increase in movements, and thus possibly arousal, to both voice conditions.

The results from ‘Arm movements’ resemble the results for ‘Arms-crossed’. Fetuses display the most inactivity in response to the recording compared to the mother’s live voice, and also when compared to control. During the first minute of stimulation (0-60s) differences can also be noted for responses to the everyday noise condition. Likewise, results demonstrated that older fetuses show an increased arousal response to the noise condition compared to younger fetuses, who appear to react less to the noise condition. This effect, however, diminishes over the second-minute of stimulation.

Significant differences between the two voice conditions can only be found for ‘Uterus touch’ frequency (30-60s) where younger fetuses touch the uterus wall significantly more during mother’s live voice than in response to the recorded voice of the mother or the everyday noise. Older fetuses show no significant differences between the two voice conditions. The same pattern can be found for ‘Uterus touch’ duration (30-60s), where responses to live voice are different to that of the everyday noise and responses to the recorded voice are similar to that of the control condition. When comparing the activity of younger and older fetuses significant differences can be observed between gestational ages in the live voice condition, with older fetuses engaging in significantly less ‘Uterus touch’ compared to younger fetuses.

Further differences between the two voice presentations can be found for ‘External touch’ (30-60s), with younger fetuses engaging more in externally directed touch during mother’s live speaking compared to the recording.

Thus it can be concluded that, based on the evidence provided, fetuses do respond differentially to the two presentation methods of the mother’s voice. Although differences between live and recorded voice are not always statistically significant, there is evidence of emerging patterns between the two conditions in conjunction with the two control conditions. So is it that older fetuses respond differentially to younger fetuses to the two voice conditions. There are still similarities between the two voice conditions, which is highlighted by the similar responses to the two when compared to control and everyday noise conditions. However, the response differences between the two variables also highlight that some form of differentiation must occur. Thus **Hypothesis 1** can be accepted.

Aim 2: Differentiation between social and non-social stimuli

Hypothesis 2a predicted that all three auditory conditions (live, recorded voice, everyday noise) would elicit a behavioural response from the fetus when compared to the silent control condition. When focussing solely on the overall results of the condition, without taking gestational age into account, ‘Face press’ appears to show a consistent difference between control and everyday noise conditions. Fetuses display more ‘Face press’ frequency and duration during the everyday noise condition compared to control, and no difference can be found between the two voice conditions. The two voice condition responses are comparable to that of the control condition, suggesting that the fetus does not respond differentially to the control condition but to the everyday noise condition.

A similar pattern is observed across other variables such as ‘Arm movements’ or ‘Uterus touch’. However, upon further inspection of the ‘Arm movements’, considering the gestational age, the pattern changes ever so slightly. It appears that younger fetuses show a stronger response to both voice conditions, and similar responses to control and everyday noise conditions can be observed. Older fetuses, on the other hand, do not show statistical differences between the four conditions, however, upon inspection of the graphs, a possible pattern appears to evolve. Older fetuses appear to display the lowest responses of activity for the live condition, marginally increase their activity for both control and recording conditions, and the highest response for everyday noise. Similarly, upon the inclusion of the gestational age, patterns change for ‘Uterus touch’ frequency and duration. Younger fetuses appear to show little to no response to the everyday noise condition, a weak response to control, more ‘uterus touch’ for and highest responses during mother’s live voice. Older fetuses, on the other hand, show similar low responses to control and live voice, and slightly higher responses to both recorded voice and the everyday noise condition.

In order to further examine the fetal response to the three auditory conditions, we can investigate the results from ‘External touch’, which is comprised of both ‘Uterus touch’ and ‘Face press’ and can thus help disclose further information about the already discussed results. Throughout the two-minute stimulation period ‘External touch’ highlights differences between the groups. Younger fetuses appear to respond the least to both recorded and noise conditions, intermediately to control, and strongest to the mother’s live voice. Furthermore, the difference between live and recorded voice is significantly different (30-60s). Older fetuses do not show any significant differences, however, the data suggests that the lowest responses are found for control, increasing slowly for live voice, then recording, with strongest responses for the everyday noise condition.

Thus, although all responses elicit a fetal response, it seems the observed response is unlike the predicted patterns, thus the **Hypothesis 2a** must be rejected. Fetuses do not show differential responses between the three auditory stimulation conditions and control, but rather show a response far more complex than anticipated.

Hypothesis 2b predicted that the everyday noise condition elicits a different response to the control condition. The results show differences between control and everyday noise conditions for ‘External touch’ and ‘Face press’. Differences for ‘Face press’ frequency and durations are present throughout the stimulation period, with a decrease in ‘Face press’ during control, and an increase in the everyday noise condition. Results for ‘External touch’, which includes both ‘Uterus touch’ and ‘Face press’, support this notion. Older fetuses primarily engage in very little ‘External touch’ during the control condition and tend to increase the response during the everyday noise condition. No such differences were observed for younger fetuses as if there was no difference between control, everyday noise conditions, and the mother’s recorded voice. Thus **Hypothesis 2b** is supported. Especially upon investigating younger fetuses responses such as ‘Arm movements’, ‘Uterus touch’, ‘Arms-crossed’, and ‘Inactivity/Resting’, it becomes clear that responses for noise in younger fetuses appear to elicit a rather weak arousal response to both the control and everyday noise condition, whereas older fetuses appear to have a somewhat stronger response to the everyday noise condition compared to the control condition.

Hypothesis 3 predicted that fetuses react differentially to maternal live voice compared to everyday noise (inanimate auditory) stimulus. The most prominent results regarding **Hypothesis 3** can be found in 'Arm movement' frequency and durations, 'Uterus touch' frequency and duration, and 'General movement' frequency measures from the first 0-15s onwards. Throughout the experiment, younger fetuses show a significant difference or tendency between the live voice and everyday noise conditions. Younger fetuses display an increased arousal response to mother's live voice, whereas a decrease in movement is displayed in response to the everyday noise condition. No such differential responses were observed in older fetuses, where all conditions appear to have a somewhat similar response strength.

Some of the differences between the two groups emerged with opposing findings. Older fetuses, for example, display a decrease in arousal in response to mother's live voice, whereas an increase in arousal can be observed in response to the everyday noise condition.

These findings are supported by findings on 'General movements' that show the same trend for younger fetuses, and no statistically significant differences for older fetuses who appear to display the weakest response in control, increasing it slightly for mother's live voice, then the recording, and the highest response can be found for everyday noise.

Responses to 'Uterus touch' frequency and duration are also rather consistent throughout the two-minute stimulation. Again, the majority of differences can be found for younger fetuses, which will display increased arousal response for mother's live voice, compared to a decrease in the everyday noise condition. Older fetuses, on the other hand, display comparably low responses for both live and control, and an increase for recording and everyday noise conditions.

In summary, **Hypothesis 3** can be accepted, as there appear to be differences in how the fetuses respond when the mother was speaking live compared to just an inanimate auditory stimulus. Having another form of control, besides the no-sound control condition, in the experiment allowed us to compare the mother's voice whether it was recorded or live, with other sound stimuli, that is the noise and the pure control conditions. The noise condition was included in the design to ensure that the observed responses are not due to the fetus simply responding to any sound when the aim is to examine whether the mother's voice was a unique stimulus.

Aim 3: Maturational differences

Hypothesis 4 predicted that the behavioural responses would be more pronounced and differentiated across the condition in more the mature, third-trimester, fetuses compared to second-trimester fetuses. The analysis of the data revealed that the strongest arousal responses can be found in the younger, second-trimester fetuses and not the older, third-trimester fetuses. There were, however, several differences between the two groups with this respect. Differences were measured throughout the 2-minute stimulation period for 'Arm movements', between the gestational groups in response to live and recorded voice. Younger fetuses increase their 'Arm movement' responses to both live and recorded voice, whereas older fetuses show a decreased response. Furthermore, in the overall analysis between gestational ages a tendency for an increased arousal response can be found for younger fetuses, whereas older, third-trimester, fetuses tend to display a decreased movement response to the mother's voice conditions. This pattern can be observed throughout the experiment in variables such as 'General movement' frequencies and durations where, additionally to the differences to the voice conditions, older fetuses show an increased response to the noise condition, whereas younger fetuses show a decreased response.

Differences in ‘Body touch’ frequency were found between gestational groups for control and everyday noise conditions. Younger fetuses increased their response during control and decreased their response to noise, whereas older fetuses showed a decreased response to control and an increased response to the everyday noise condition. The opposite was true for ‘Face touch’, with fetuses displaying differences only for mother’s live and recorded voice. Again, an increase in arousal was found for both conditions in second-trimester fetuses, while older fetuses tended to respond with less ‘Face touch’ to both voice conditions.

‘Uterus touch’ showed differences between groups for mother’s live voice and the everyday noise condition. Younger fetuses showed an increase in the mother’s voice compared to older fetuses and no differences were found regarding the recorded voice condition. For the everyday noise condition, however, younger fetuses hardly showed a response, while older fetuses showed an increased response.

Overall it was found that younger fetuses tend to display more arousal responses compared to older fetuses, such as older fetuses move less frequently to the mother’s live and recorded voice compared to younger fetuses. Regarding the everyday noise condition, however, older fetuses display a stronger arousal response, whereas younger fetuses responses are rather weak. It is possible that the younger fetuses display more arousal to the mother’s voice as it is still a relatively novel stimulus for them, while older fetuses familiarised with her voice already. Hearing structures are formed and functional from 16wGA (López-Teijón et al., 2015; Sohmer, Perez, Sichel, Priner, & Freeman, 2001), and fetuses are expected to respond to sound from 28 wGA (Brezinka et al., 1997). Since the cut-off point between second- and third-trimester was between 27 and 28 weeks, it could be possible that fetuses in the younger group are just beginning to hear the mother’s voice, but not all of them are yet capable of hearing and recognising her voice at the beginning of the second-trimester. Thus it is possible that the increased arousal response to the mother’s voice condition reflects a novelty response in younger fetuses, while the older fetuses who have been exposed to the mother's voice are more familiar to it, hence they are showing a decrease in response, supporting previous findings (Marx & Nagy, 2015). Thus the overall decreased responsiveness of older fetuses is not purely due to the limited space, but more to the increased CNS maturation, which is related to a decrease in movements over time. On the other hand, younger fetuses are more easily aroused and are just beginning to familiarise themselves with the novel sounds from their environment as their CNS and physical development advances throughout pregnancy. These findings suggest that **Hypothesis 4**, which proposed that behavioural responses would be more pronounced and differentiated across the condition in more the mature, third-trimester fetuses compared to second-trimester fetuses, is supported by our data.

Aim 4: Time-interval analysis

Hypothesis 5a examined fetal responses throughout different time-frames of the 2-minute stimulation period, in order to examine whether fetal responses change and evolve over time, and how early responses to the stimulation can be found. It was hypothesised that there would be differences in the response strength over the course of the stimulation. Alongside **Hypothesis 5a** it was hypothesised by **Hypothesis 5b** that fetuses would show responses to the stimulation as early as within the first 10-15s.

Some of the fetal responses were relatively steady throughout the stimulation period. Fetuses pressing their faces against the uterine wall, for example, was the strongest to the everyday noise stimulus, followed by mother's live voice, while the responses to the voice recording were comparable to that of the control condition. These findings were consistent across the entire stimulation period for both 'Face press' frequency and duration measures.

'Arm movement' responses emerge immediately after the onset of the stimulation, and the differences are most prominent between older and younger fetuses for both voice conditions. Overall it seems that the older fetuses tend to respond with a decrease in movement while younger fetuses show increased arousal for the voice conditions. ‘Arm movements’ in the noise condition, on the other hand, showed the opposite pattern. Older fetuses increase their activity levels towards the everyday noise condition, whereas younger fetuses appear to respond with a decrease. This difference in the voice conditions appears – at a tendency level - from the earliest time interval (0-10s), however, the maturational difference in the response to the everyday noise condition does not become apparent until a few seconds later (0-15s). These responses become stronger and more differentiated throughout the 2-minute stimulation period, and peak at 0-30s and 0-60s for all three but the control conditions. From 60-90s it is mainly the differences in the live voice condition that are still significant, second-trimester fetuses decrease their arousal response to the recording and older fetuses decrease their arousal response to the everyday noise condition.

‘Arm movement’ duration measurements are slightly different compared to the frequency measurements. The first tendencies emerge at 0-15s into the stimulation, with significant differences between age groups for the live voice condition and a tendency for the recording. These differences remain consistent during 0-30s and disappear in the second minute of stimulation (60-90s, 90-120s, 60-120s), but analysis of the ‘General movement’ frequency and duration variables, which include both ‘Arm movements’ and ‘Head movements’ together, underline the general arousal responses from younger fetuses and attentive responses from older fetuses throughout the experimental stimulation period.

Differences in ‘Uterus touch’ become apparent within the first 0-10s of stimulation and are most pronounced between gestational ages for live voice, with yet again, an increase for younger fetuses compared to older fetuses. In the noise condition, however, older fetuses increased touch, compared to younger fetuses, who barely responded to the noise condition but responded very strongly in both voice conditions. These findings are consistent throughout time intervals of the first minute of stimulation (0-10s, 0-15s, 0-30s, 0-60s). After the first minute of stimulation older fetuses decreased their arousal response to the everyday noise condition, however, a tendency still remains (60-90s), and the differences disappear at the end of the two-minute stimulation (90-120s).

For the two-minutes of stimulation (0-120s), the frequency of ‘Uterus touch’ is different in both the live voice and the everyday noise conditions, while the duration of ‘Uterus touch’ shows a significant age-related difference only for the live voice condition (0-120s). These changes are coming from the first minute of stimulation (0-60s) because the responses have decreased and are not significant for the second minute of stimulation (60-120s).

Overall it has become apparent that there is a need to analyse different time intervals, as important details and significances can easily be overlooked if results from variables are averaged over 120s.

‘Face press’, ‘Arm movements’, and ‘Uterus touch’ are the most prominent and steady variables throughout the stimulation period, showing little variation, which could lead to conclude that there is no difference throughout the different time intervals. However, other variables, such as ‘Body touch’, ‘Self touch’, ‘External touch’, ‘General Movements’, ‘Arms-crossed’, or ‘Inactivity/Resting’, change throughout the stimulation period. Furthermore, the increase and decline in the strength of the responses over the course of stimulation could be observed. Thus it can be suggested that responses do change throughout the stimulation period, with varying degrees of active and inactive periods. Thus, **Hypothesis 5a**, that there would be differences in the response strength over the course of the stimulation can be accepted. **Hypothesis 5b**, that fetuses would show responses to the stimulation within the first 10-15s, can also be accepted as earliest differences could be observed in the earliest analysed timeframes.

General Discussion

Many factors determine whether and how the fetus will be able to perceive sounds from the external environment. These factors are sounds from within the mother's body, sound transmission and readiness of the fetal ear, attenuation of sounds by fluids, tissues and bone conductivity, and the sensitivity of the hearing mechanism, which is largely dependent upon fetal maturity (Armitage et al., 1980; Birnholz & Benacerraf, 1983; Gerhardt et al., 1996; Gerhardt & Abrams, 2000; Lecanuet & Schaal, 1996; McCorry & Hepper, 2010; Querleu et al., 1988; 1989; Sohmer, Perez, Sichel, Priner, & Freeman, 2001).

The earliest responses to acoustic stimulation have been discovered at 19 wGA in a few fetuses, whereas all fetuses become responsive at 27 wGA (Shahidullah et al., 1994). Due to the nature of our experimental design, fetuses from 20 wGA until 27 wGA were grouped together in the younger, second-trimester, group and fetuses from 28 wGA onwards were grouped into the older, third-trimester, group. If younger fetuses would not be able to hear the acoustic stimuli we would have found hardly any variability between conditions, however as this experiment has demonstrated the younger age group had the strongest behavioural responses to both maternal voice conditions, which leads to conclude that they were indeed able to hear and respond to the stimulation, even if still unable to discriminate between a recording and live spoken voice.

The maternal abdomen acts as a filter, which attenuates high frequencies more than low frequencies. This is most likely to lead to an alteration of the perception to the exposed sound (Savio, Cárdenas, Pérez Abalo, Gonzalez, & Valdés, 2001; Shahidullah & Hepper, 1994; Sinnott & Aslin, 1985; Spence & DeCasper, 1987). Regardless of the alteration of the sound, the fetus will become familiar with the perceived sound as this is what will be perceived as familiar and therefore 'normal' to them. Due to the nature of the filter, properties of the maternal voice have been found to be enhanced rather than attenuated (Richards et al., 1992). Further examination of fetal sound reception in the sheep showed that prosodic information, such as rhythmic and intonation aspects were retained whereas high-frequency information, such as consonants, are attenuated (Griffiths, Brown, Gerhardt, Abrams, & Morris, 1994). Further examination has proposed that intelligibility of speech in utero is reduced by 32% compared to ex-utero sound presentation (Richards et al., 1992). Thus sounds reaching the fetuses are perceived rather differently, especially when traveling through the maternal abdomen until they reach the fetal cochlea. However, since in this experiment, the recording was of the mother’s voice and it has already been shown that the nature of the mother’s voice is enhanced rather than attenuated (Richards et al., 1992). It would be plausible to assume that the observed responses to the recording of the maternal voice are due to the unique properties described above. Fetuses in our sample did not discriminate between the forms of maternal voice presentation and showed almost equally strong responses to both voice conditions.

Responses to the everyday noise condition are different between the two age groups. Second-trimester fetuses barely respond to the noise condition. A possibility for the observed lack of response might be that the everyday noise stimulus is filtered out by the maternal abdomen so that the immature auditory system is unable to perceive the delicate sound, which would explain the similarity for noise and control conditions. Older fetuses, on the other hand, increase their responses to the everyday sound, which is likely to be due to the advanced maturation of both auditory and central nervous system (Graven & Browne, 2008; Kinney, Karthigasan, Borenshteyn, Flax, & Kirschner, 1994; Krmpotić-Nemanić, Kostovic, Kelović, Nemanić, & Mrzljak, 1983; Sachis, Armstrong, Becker, & Bryan, 1982). However, it needs to be pointed out that the fetal uterine environment has inconsistent sound levels (Querleu et al., 1988) and that the sound environment has not been studied over the course of gestation, thus it remains unclear whether the observed differences are purely due to the maturational changes of the fetus, or whether the possibly changing abdominal environment also impacts upon the sound experience.

Contrary to previous studies, which pre-exposed the fetus to a specific passage, often a story of nursery rhyme, prior to examination, for either a short (Jacquet et al., 2009; Kisilevsky et al., 2003; Kisilevsky & Hains, 2011; Shahidullah et al., 2007) or a long amount of time (DeCasper et al., 1994; Krueger et al., 2004), and then examined fetal responses; this study examined the mothers voice in the most natural state possible. Reading a story or nursery rhyme alters the prosody of the voice (Blaauw, 1994), and exposing the fetus to such passage and then examining the responses thereafter are more likely to reflect early memory formation and recognition capabilities than responses to the mother as a unique stimulus. Even newborns display a preference for the mother's natural voice over motherese (Shahidullah et al., 2007), thus this experiment examined mother's spontaneous, and therefore most naturally occurring voice, where specific pre-exposure is not necessary. Although one might argue that the mother did record herself prior examination, it needs to be said that the recordings and the live spoken voice were dissimilar. Despite the dissimilar voice stimulations, the fetus was capable of responding to both live and recorded voice in a similar fashion. Second-trimester fetuses' responses to the live spoken voice appeared to be stronger, however, overall the responses to both voice conditions were very alike, strong and mostly different to control and the everyday noise condition as well. Third-trimester fetuses continued to respond equally to both live and recorded maternal voices.

Previous research (Shahidullah & Hepper, 1994) investigated rudimentary learning and short-term memory in fetuses using a habituation paradigm. Findings suggest that discrimination of a habituated and novel stimulus is present from 35 wGA, but not necessarily at 27 wGA (Shahidullah & Hepper, 1994). Data from this experiment supports these findings partially. In this sample younger fetuses showed no differential responses between the recorded and live voice of the mother. However, younger fetuses did show differential responses between everyday noise and the control conditions. In this experiment younger fetuses responded with an overall increase of their movements in response to both maternal voice conditions, which might be due to an arousal response to the mother's voice, which may be due to still the developing auditory responses in the younger group and that hearing the mothers' voice may be a more recent development in this group (Shahidullah et al., 1994).

Older fetuses, on the other hand, were significantly less active during both voice conditions compared too younger fetuses. Like younger fetuses, older fetuses also showed no significant differences between voice conditions. However, increased responses appeared to emerge between everyday noise and voice conditions. Thus possible discrimination between voice and environmental stimuli, in this sample, might also reflect learning and primitive memory formation, supporting previous results (Shahidullah & Hepper, 1994), and also suggest that age-related differences emerge much earlier than previously reported.

Previous studies reported emerging differences between 28-32 wGA, as increased developmental discontinuity becomes evident through habituation performance (Groome, Gotlieb, Neely, & Waters, 2008) and vibroacoustic stimulation (Buss et al., 2009; Kisilevsky et al., 1992), suggesting an underlying increase of rapid neural myelination as well as advancement of vagal and cortical processes (Kinney et al., 1994; Sachis et al., 1982). Similar developmental shifts can be observed during the first year of the infant's life, which is due to important underlying neurological processes (Zeanah, Boris, & Larrieu, 1997), thus it is feasible to argue that the fetus is undergoing similar changes in neurodevelopmental processing. Main differences in responses have been observed between the two gestational groups, with younger fetuses appear to be more arousable compared too older fetuses. Older fetuses might experience an increased cortical and inhibitory processing thus may respond with decreased movements to the familiar voice stimulus.

Overall, the observed decrease in general movements in third-trimester fetuses supports previous findings (Marx & Nagy, 2015; Nijhuis, 2003; Shahidullah & Hepper, 1994). The observed decrease in general movements could be due to increased nervous system maturation, such as increased cognitive functioning (DiPietro, Costigan, & Voegtline, 2015; Shahidullah & Hepper, 1994). Increased neurodevelopmental changes from 32 wGA onwards could thus reflect higher levels of cortical control. These might relate to increased inhibition and response control and could explain why older fetuses exhibit a decrease in movements (DiPietro et al., 2015). These increases in response control have been suggested to lead to a decreased excitability by familiar stimuli and thus allow the fetus to increase voluntary intentional responses (Zoia et al., 2007). Previous reports struggle to find consistent results. Some studies report a decrease in fetal motility as it gets closer to term (Roodenburg et al., 1991), whereas others fail to show changes in motility during the third trimester (Manning, Platt, & Sipos, 1979; Patrick, Campbell, Carmichael, & Probert, 1982). Thus results as to whether the fetus decreases movements towards the end of term remain controversial, however, it is well established that fetuses' actions progress from uncoordinated to integrated and well-differentiated patterns of movement (Amiel-Tison et al., 2006). Also, a decrease in general movements could resemble an orienting response of the fetus to the familiar stimulus (Voegtline et al., 2013) or alternatively, the mother's voice might have a calming effect on the third-trimester fetus (Seltzer, Ziegler, & Pollak, 2010). Regardless of the underlying reason, results from this experiment demonstrate the advancement of third-trimester fetuses' neurodevelopment and increased autonomous and cortical control.

The observed fetal responses can be found almost immediately after the onset of the stimulation, within the first 10-15 seconds. The time-interval analysis revealed that the observed changes remain rather consistent throughout the stimulation period, although some responses diminish slowly over the 2-minute stimulation period. Thus the claim that 2 minutes are not enough and a lengthier exposure is needed to observe the effects, cannot be supported (Cave et al., 2015). Fetal responses appeared to be strongest during the first 30 seconds, revealing strong and clear results. This suggests that there is no need to subject mother and fetus to lengthier stimulation and examination than needed.

Chapter 3: Touch experiment

Experiment 2: Frame-by-frame analysis of fetal behavioural responses to the touch of the mother's abdomen

Introduction

Tactile stimulation in animal studies

Touch is an important mechanosensory stimulus across species. Tactile stimulation has been shown to have a positive impact on growth and development in a wide range of organisms ranging from worm larvae, rats to human child development (Ardiel & Rankin, 2010). Animal studies support the notion that tactile stimulation reduces stress, improves attachment and facilitates early development (Adamson-Macedo, 1990; Field, 2000; Field et al., 1986; Scafidi et al., 1990). For example, Increased physical tactile interaction in worms results in increased growth and adult responsiveness to touch (Gonzalez, Lovic, Ward, Wainwright, & Fleming, 2001), and maternal licking in rats results in a profound effect on the physiology and behaviour of the grown adult (Liu, Diorio, Day, Francis, & Meaney, 2000). Increased tactile stimulation, such as holding a rat for 10mins led to superior maze performance, thus suggesting increased cognitive performance compared to control animals which were not handled (Bernstein, 1952). On the other hand, tactile deprivation from maternal-infant separation in rats has led to the reduction of growth hormone secretion related to generally disturbed endocrine functionality (Schanberg & Field, 1987). Stroking of maternally deprived rat pups led to the reversal of the endocrine disturbance, helping the organism to return to homeostasis, whereas other forms of vestibular and kinesthetic stimulation were unsuccessful (Schanberg & Field, 1987).

Tactile stimulation in humans

Studies on humans also indicate that tactile stimulation can reduce stress, improve parent-infant attachment and enhance infant development (Adamson-macedo, 1990; Field, 2000; Field et al., 1986; Meaney, Lozos, & Stewart, 1990; Scafidi et al., 1990).

In human children, developmental delay can often be observed in children who have received inadequate sensory stimulation (Carlson & Earls, 1997; Frank, Klass, Earls, & Eisenberg, 1996; Goldfarb, 2015). The most common way of studying touch deprivation in humans, without intervening, was to study institutionalised children and infants (Carlson & Earls, 1997; Frank et al., 1996; Goldfarb, 2015; Gunnar, 2001; D. E. Johnson, 2000). For example, in institutionalised infants, sensory deprivation can lead to developmental delays such as cognitive delay, growth impairment, attachment disorders, delay in motor function, and a weakened immune system (Carlson & Earls, 1997; Frank et al., 1996; Goldfarb, 2015). Furthermore, on top of the already identified growth and cognitive delays, it has been found that increased cortisol levels in neglected children resulting from tactile deprivation led to increased behavioural disorders (Carlson & Earls, 1997). Other negative effects stemming from tactile deprivation can be observed in children growing up in orphanages, who lose about 1 month of linear growth per 2-3 months spent in institutional care (Johnson, 2000) and experience similar delays leading to retardation (Gunnar, 2001).

Previously these developmental difficulties were thought to be due to maternal deprivation, or sensory deprivation in general, however studies exploring the effects of increased tactile stimulation on institutionalised infants found that increased mechanosensory stimulation lead to higher scores on developmental assessment tests compared to infants who did not receive such stimulation (Casler, 1965; Hopper & Pinneau, 1957). An additional 10 mins of handling of infants has led to a decrease in regurgitation (Hopper & Pinneau, 1957), and additional 20 mins of tactile stimulation, per day for 10 weeks, has led to higher developmental scores (Casler, 1965). Maternally deprived preterm neonates also benefit from human tactile stimulation, for example through tactile stimulation by a surrogate parent, and even more so from kangaroo-care (Feldman, Weller, Sirota, & Eidelman, 2002a), suggesting that tactile stimulation is special and important for appropriate development (Schanberg & Field, 1987). Institutionalised infants show neurodevelopmental differences with deficits on tests of visual attention', memory, and mediated learning as well as inhibitory control (Pollak et al., 2010). Research on these developmental deficits in institutionalised children has highlighted the importance of tactile stimulation and the lack thereof (Ardiel & Rankin, 2010; Blackwell, 2000). Interestingly it has been proposed that neglectful parenting has more devastating effects on the developing children than battering or physical abuse does (Egeland & Sroufe, 1981).

The timing of neglect has a profound impact on the developmental outcomes of the infants. Early neglect in infancy has been shown to damage parts of the brain such as the *locus ceruleus*, which is involved in regulating impulsiveness, anxiety, and sleep (Buranasin, 1991; Frank et al., 1996; Holden, 1996). Although the mechanisms behind the relationship of tactile neglect and behavioural maladaptation remain unclear, there is emerging evidence for environmental interactions between the endocrine system, hormonal influences and behaviour, cognitive, and physical development (Carlson & Earls, 1997; Green, Campbell, & David, 1984). These studies have generated interest in the importance of tactile stimulation for appropriate development and have led researchers to investigate the effects of tactile stimulation on the term- and premature newborns.

Tactile stimulation and the newborn

Affective touch between mother and child are commonly observed in healthy relationships. The earliest forms of touch examined are between a mother and child at birth. As is recommended by the World Health Organisation (WHO) and American Academy of Pediatrics (AAP) healthy term infants are to be given to the mother immediately after birth to promote skin-to-skin contact (Gartner et al., 2005; The World Health Organization, 1999). Mother-newborn interaction promotes interaction between the two parties and allows mothers to promote verbal and tactile comfort (Gray, Watt, & Blass, 2000) and to express maternal affection (Moore et al., 2016). Early skin-to-skin contact within the first hours of life has been demonstrated to aid newborns' self-regulatory behaviours and stress response promoting the transition to extra-uterine life (Ferber & Makhoul, 2004).

Infant massage, a widely applied form of touch, has revealed to increase cognitive development, displaying more mature orientation, motor, higher state-regulatory and habituation scores on the Brazelton Neonatal Behavioural Assessment Scale (Brazelton, 1973; Field et al., 1986; Mathai, Fernandez, & Mondkar, 2001; Scafidi et al., 1986) after massage. These effects persisted even at 2 years of corrected age in a study, with the experimental 'massage' group scoring higher on the Bayley Mental and Motor Scales (Bayley, 1993) and showed fewer neurological soft signs (Procianoy, Mendes, & Silveira, 2010).

The importance of touch on premature infants

Studies have focussed on the importance of tactile stimulation in sensitive groups such as premature infants. Premature infants spend the most time in incubators, isolated from human tactile stimulation they would normally receive. Several studies which explored the effects of mechanosensory stimulation in premature neonates indicated facilitated growth, weight gain and cognitive development, displaying more mature orientation, motor, more stable state and better habituation, decreased stress and increased active sleep (Dieter et al., 2003; Feldman, Weller, Sirota, & Eidelman, 2002b; Field et al., 2004; Harrison, Williams, Berbaum, Stem, & Leeper, 2000; Vickers, Ohlsson, Lacy, & Horsley, 2004; Wang, He, & Zhang, 2013), highlighting the importance of tactile stimulation on the developing premature infant.

Sensory stimulation of premature neonates (31-34 weeks GA) receiving at least one hour of kangaroo care, a source of somatosensory stimulation, every day, for two weeks scored higher on motor and mental domains of Bayley‘s scales of Infant Development (Bayley, 1936; 1993) during follow-up at 6 months, compared to the control group who did not receive such intervention (Feldman, Weller, Sirota, & Eidelman, 2002a). Similarly, Harrison et al.’s study (2000) also found that preterm infants born at 27 weeks of gestation were more relaxed, showed accelerated motor development, decreased stress and increased active sleep after being touched (Harrison et al., 2000).

Studies examining the effects of maternal touch on high-risk infants in the form of infant massage reported a decrease of developmental delay, increased infant responsiveness, and increased maternal affectionate touch benefits both the infant and the mother (Abdallah, Badr, & Hawwari, 2013; Field, Diego, & Hernandez-Reif, 2010a; Weiss, Wilson, & Morrison, 2004). Weiss, Wilson, and Morrison (2004) examined maternal touch during feeding times on low birth weight infants and analysed the touch and other facets of caregiving behaviour such as the frequency of the administered touch on developmental outcomes. Findings from this study indicated better visual-motor skills for infants at 1 year of age when mothers engaged in more stimulating touch, whereas the increased frequency of maternal touch was associated with more advanced motor development (Weiss et al., 2004). In Abdallah et al. (2013) premature infants received massage therapy from their mothers each day over the course of 10 days for an hour. Findings showed decreased pain responses and higher cognitive scores at 1 year of age. Further research examined the effect of touch on both pregnant mothers and their newborns by performing a light, moderate, or strong pressure massage twice a week over the course of 12 weeks (Field, Diego, & Hernandez-Reif, 2010a)4. The largest effects were observed for medium pressure touch in both mothers and infants (Field, Diego, & Hernandez-Reif, 2010a). Mothers showed reduced depression by the end of treatment as well as reduced stress responses. Infants showed increased growth and development compared to the control group (Field, Diego, & Hernandez-Reif, 2010a). Further studies investigating the effects of massage therapy showed that infant massage and holding of the infant has been found to reduce stress levels, not just in the infant but also in mothers (Neu, Laudenslager, & Robinson, 2008). Studies examining biochemical and physiological effects of touch noted an increase in oxytocin levels and decrease in cortisol levels and physiological changes such as decreases in heart rate as well as blood pressure (Heinrichs, Baumgartner, Kirschbaum, & Ehlert, 2003; Henricson, Berglund, Määttä, Ekman, & Segesten, 2008). Biochemical maternal changes during pregnancy have been found to affect fetal development (Weinstock, 2008). It is plausible to assume that mothers' external touch of the abdomen could affect the fetus via tactile stimulation by the movements of the hands across the abdomen while the connected muscles of the following body result in internal muscle and body movements, which accompany the external touch. Thus, when the mother touches her abdomen the fetus may feel a combination of somatosensory stimulation from the mother's external hand movements and the internal secondary effects of the body movements that passively follow the hand movements. Further effects could be biochemically through hormonal changes, such as the reduction of cortisol or increase of oxytocin (Feldman, Weller, Sirota, & Eidelman, 2002a).

Maternal touch therefore appears to have unique and superior characteristics compared to other purely external tactile stimulation administered by secondary sources.

The so far presented evidence illustrates that early tactile stimulation has an effect across species. In animals, touch reduces stress, improves attachment, facilitates early development, and the effects continue to adulthood

(Adamson-macedo, 1990; Field, 2000; Field et al., 1986; Gonzalez et al., 2001; Liu et al., 2000; Scafidi et al., 1990). In term human newborns touch aids self-regulatory behaviours and stress responses, while infant massage enhances cognitive development, with more mature orientation, motor, higher state-regulatory and habituation scores on the Brazelton Neonatal Behavioural Assessment Scale (Brazelton, 1973; Field et al., 1986; Mathai et al., 2001; Scafidi et al., 1986). In premature infants touch facilitates growth, weight gain and cognitive development, increases orientation, motor, range-of-state and habituation behaviours, decreases stress, and increases active sleep (Dieter et al., 2003; Feldman, Weller, Sirota, & Eidelman, 2002b; Field et al., 2004; Harrison et al., 2000; Vickers et al., 2004; Wang et al., 2013).

If touch already affects premature infants, it is possible that touch has an active role in the development of the fetus as well, the observed positive effects of touch give rise to the idea that tactile stimulation plays an important part in fetal (in-utero) development.

Touch and the fetus

Since research has highlighted the importance of tactile stimulation on animals, human orphans, and maternal touch on premature newborns, term newborns, and infants, it is possible that prenatal tactile stimulation is important to fetal development, too.

Touch is the first sense to emerge during fetal development between 8-9 wGA (Hooker, 1952; Humphrey & Hooker, 1959). During the early stages of gestation fetal touch is unlike adult's conscious perception of touch as it develops over time until the end of pregnancy. By 32 wGA the body is sensitive to 'a gentle stroke of a single hair' (Montagu, 1971). During the early stages of gestation processing of touch, stimuli is a low-level process of the immature CNS occurring in the brain stem and spinal cord (Craig, 2002; 2011; Kida & Shinohara, 2013; Marx et al., 2005; McGlone et al., 2014). The brain stem plays an important role in the early processing of proprioceptive and tactile stimulation and is proposed to be enabling a primary form of consciousness.

The hindbrain cortices are involved in timely mechanisms for sensorimotor control needed for coordinated voluntary skeletomuscular control of movement (Marx et al., 2005). The ‘brain stem selection triangle’ has been proposed between target selection, action selection, and motivational ranking based on the body’s vital needs for primary conscious experience (Merker, 2007). This suggests that the fetus does not necessarily need a fully functional CNS in order to consciously and voluntarily respond to stimulation, as these functions are part of the ancient brain structures which develop early on during gestation.

It has been proposed that the earliest fetal consciousness is mainly of tactile and proprioceptive nature (Delafield-Butt & Gangopadhyay, 2013). During early fetal development, most sensory organs are cut off from stimulation by morphological changes. Although the fetus is capable of self-regulating movements, the sensory organs have been found to have reduced function pre-partum (Kisilevsky et al., 1992; Moore & Linthicum, 2007; Shahidullah et al., 1994). The eyelids are gown and fused over the cornea and will not open until 6 months GA, ear ossicles are developed but transmission remains blocked until the last months of gestation, and the nostrils are closed by epithelial plugs until the last trimester, leaving the fetus with a primarily tactile and proprioceptive experience during the first and second trimester of its life (Delafield-Butt & Gangopadhyay, 2013). Thus, despite the continuing development of the fetus, we can be sure that the fetuses examined in the following experiment are capable of experiencing external tactile stimulation and are capable of responding, even if not consciously but by the means of cortical feedback loops reacting to stimulated afferents (Marx & Nagy, 2015; Merker, 2007).

As a sense, touch, is unique due to its dual properties; it is both perceptive and receptive thus allows the person being touched to simultaneously touch the source back. Even self-touch results in simultaneously touching and being touched by the own body (Katz, 1989). The developing fetus is constantly passively stimulated by the uterine environment, the placenta, the umbilical cord, amniotic fluid, and the uterine surface, and touches its body passively due to environmental restrictions or actively as self-initiated movements develop and actively stimulated through external stimulation through the abdominal wall (Lagercrantz & Changeux, 2009). Hence touch has a prominent presence throughout the fetal development, especially since it is the first sense to start development and tactile stimulation of the fetus occurs both actively and passively on a daily basis, suggesting its likelihood for its importance in fetal development.

Fetal hand-to-face interactions appear early on during the course of development at 8 to 10 wGA. The face appears to be a preferred location of self-stimulation, due to its densely trigeminal innervation, making it very sensitive to the perception of tactile stimulation compared to other body areas such as the thorax or stomach, which are rarely touched (Piontelli, 2010). During early development, the fetus prefers to touch sensitive, richly innervated areas but also touches the cranium near the insensitive areas of the fontanelles. Throughout development tactile sensitivity increases and soon the fetus will predominantly engage in touching richly innervated areas such as the face (Piontelli, 2010). Such movements are becoming goal-oriented (Trevarthen, 1985), that is intentionally initiated by 22 wGA (be consistent) (Zoia et al., 2007). In the last 4-5 wGA the fetus increasingly touches the nape, often with both hands (Piontelli, 2015).

The feet are another sensitive area and with their disproportionately long arms, fetuses frequently touch their feet and push their feet against the uterine wall and mothers often report feeling such movement from 18 wGA (Bradford & Maude, 2017; Saastad, Ahlborg, & Frøen, 2008). Even at rest, the feet are in contact with the uterine wall. Fetuses rarely touch their backs or buttocks actively, but these areas often passively touch or push against the uterine wall (Piontelli, 2010).

Stimulation of innervated regions creates an ‘auto-stimulatory feedback loop’, meaning that the action of touch between fingers/hands and the touched area simultaneously results in a proprioceptive response at the contacted area – the sensation of touch in fingers and innervated region, respectively (Piontelli, 2010). Between 10-14 wGA movements become isolated into individual actions increasing goal-direction towards the body (Piontelli, 2010; Trevarthen, 1985). By 14 wGA quantified kinematic analyses analysed movement action patterns and revealed differentiated motor planning towards a ‘goal’ (Castiello et al., 2010). In twin pregnancies, twin-directed movements can be observed from 18 wGA, which have been argued to indicate a primary ‘social awareness’ (Castiello et al., 2010). Kinematic studies of singleton pregnancies have confirmed operationality of motor planning by 22 wGA (Zoia et al., 2007).

During the second trimester, fetal movements are becoming more prospectively controlled and sensory anticipation can be observed. This is reflected by anticipatory mouth movements when the hand of the fetus is directed towards the mouth, by 19 wGA, suggesting inter-sensorimotor anticipatory coupling (Myowa-Yamakoshi & Takeshita, 2006). By this time fetal movements are executed with a degree of precision requiring coordinated prospective control, which can be seen in the execution of movements such as turning the body, ‘bicycling’ with the legs, touching the umbilical cord, placental lining, the own body, or a twin fetus (de Vries et al., 1982; Piontelli, 2010; Piontelli et al., 1997). After birth, the newborn displays body movements coordinated with limb, head, and eye movements towards objects in their focus or stimuli like the mothers’ voice (Alegria & Noirot, 1978; Trevarthen, 1984).

The Role of Affective Touch Biomechanical Mechanisms

Current research suggests that affective touch plays an important role in social interactions and is associated with positive health benefits (McGlone et al., 2014). Tactile stimulation is often sought by children and is beneficial to their behavioural and emotional development (Field, 2002). As previously mentioned, the neglect of positive tactile stimulations as is commonly observed in orphanages can result in negative behavioural, emotional, and physical developmental effects of the child (Spitz, 1945). As is proposed by neurophysiological studies, the positive tactile stimulations are proposed to be perceived by a group of unmyelinated, low threshold afferents, also known as C-tactile (CT) afferents (McGlone et al., 2014).

Recent research has therefore focused on the biological factors underlying social touch; with a primary focus on the C tactile (CT) afferents (Morrison et al., 2010). CT fibers are proposed to play part in the neurological foundations of attachment and affective processing of touch, in the construction and integration of the sense of self and others, and social interactions and communication (I. Morrison et al., 2010; Olausson et al., 2010). Thus in relation to the functional role of the CT system the 'affective touch or social touch hypothesis' has been proposed (Olausson et al., 2010). CT fibers are the most sensitive to gentle touch with a speed of (1–10 cm/s), a comfortable skin caress, which is reported as a sensation of pleasant touch (Vallbo et al., 1999). Another factor related to CT firing frequency is skin temperature (Croy, Sehlstedt, Wasling, Ackerley, & Olausson, 2017). Activation of CT afferents has not only been found to be most sensitive to gentle touch, but has also been found to be the highest for touch with skin-like temperatures, suggesting the system is well adapted to human touch (Croy et al., 2017), which highlights why skin-to-skin contact is not the same tactile contact as through clothing which acts as an insulating barrier and limits the benefits of skin-to-skin contact between mother and child. Skin-to-skin contact for the first two hours after birth have been shown to positively influence mother-infant interactions, improve infant's self-regulation and irritability, and also mothers sensitivity one year postpartum (Bystrova et al., 2009). Infants without direct skin-to-skin contact but who were swaddled and placed into the mother's arms did not show these benefits one year postpartum (Bystrova et al., 2009). Infants who were taken from their mothers and reunited 2 hours after birth still showed suboptimal patterns after delivery, similar to those infants who were separated for the first two hours and then reunited with their mothers following the two hours, suggesting that skin-to-skin contact between mother and newborn during the first two hours postpartum are of significant importance for development and future dyad interaction between mother and child (Bystrova et al., 2009; Klaus et al., 1972). It has been proposed that, although the underlying mechanisms are yet to be fully explored, early skin-to-skin contact between mother and child exerts positive effects on their relationship and development. These findings are likely to be related to oxytocin release, which does not occur when the child is wrapped in an 'insulating layer' of fabric or clothing, suggesting that the underlying mechanism is related to the skin response to tactile stimulation (Bystrova et al., 2009).

Unlike the role of the Aβ afferents, which identify factual information about the features of mechanical skin deformation and quickly relay said information to the brain, the CT system is proposed to identify and boost the emotional effects in regard to the incoming touch stimuli, i.e. from a friendly conspecific (McGlone et al., 2007; 2014). The CT system is proposed to be involved in supporting feelings of comfort, pleasure, reward, confidence, and security when interacting with parents, kin, lovers, or friends respectively, and may play a role in emotional attachment formation with another individual through underlying hormonal responses, as the CT system is proposed to be deeply embedded with the brain's complex emotional response system, although the exact mechanism of the CT system remain unclear (Vallbo et al., 2016).

The affective touch hypothesis tightly links sensory inputs and emotional responses contributing to both physical well-being and mental health of an organism by affecting its physical and chemical compositions (Craig, 2002; 2008). However, the examination of the direct effect of the CT system on emotional responses proves to be difficult. Reason for that being that the interpretation of touch is highly dependent on contextual factors, such as the social relationship between the two individuals and the emotional state of the recipient of the touch. Moreover, along with CT activation, the Aβ system is simultaneously activated in order to capture the entire cutaneous deformation, even when social touch is applied, which adds another layer of difficulty in order to tease the role of each of the systems apart with regard to their role in social touch. Studies investigating patients with neuropathy (loss of myelinated CT afferents) found that the stimulation of the skin can elicit a weak and inconsistent sensation of 'pleasant' touch, suggesting that the two systems (Aβ and CT) are important for the processing of a full sensation of social touch (Olausson et al., 2002), thus it is not only the stimulation of CT fibres that is related to a sensation of 'pleasant' touch but Aβ fibres are also related. However, psycho-neural correlational analysis (Vallbo, Olsson, Westberg, & Clark, 1984) have revealed evidence suggesting CT activation is related to hedonic effects. Further evidence comes from animal studies where in vivo stimulation of the CLTMR system (C low threshold mechanosensitive receptors) of mice had positive reinforcing effects on the behaviour suggesting an anxiolytic potential (Vrontou, Wong, Rau, Koerber, & Anderson, 2013). Thus currently the affective touch hypothesis of the CT system appears to be promising, although further exploration of the CT system and the central connections are needed in order to refine the social touch hypothesis, which might eventually help explain the survival value of a surplus tactile system (Vallbo et al., 2016).

The Aβ systems somatosensory afferents receive tactile information from Merkel Cells (MCs), which were first found in volar cells of the fetus of 18 wGA. By 25-32 wGA these diminished and MC cells were found to be distributed across the body similar to that of the adult's skin (Boot, Rowden, & Walsh, 1992). Although the first direct tactile stimulation between mother and newborn occurs postpartum, the mother engages in indirect tactile stimulation of the fetus much earlier. Mothers stroke their bump regularly consciously and unconsciously during pregnancy, stimulating the fetus indirectly through the maternal abdomen thus passively stimulating the skins tactile receptors which are already present at the end of the first trimester and have matured by the end of the second beginning of the third trimester.

Although there is still much to be discovered about the skins CT system, it appears to play a significant part in the interpretation of the applied touch - mostly related to social touch, such as pleasantness and comfort, as it is connected to the brain's emotional response system (Olausson et al., 2002; Vallbo et al., 2016). Maternal stimulation might allow for the development of the first connection between the fetus and mother is likely to be aided by the CT system in connection with the mechanical inputs processed by the Aβ afferents and connected cortical areas.

The skin's two tactile systems are not only important for the fetus but also for the mother. A mother's touch of her own abdomen is most likely to be perceived differently to her partner's touch and a stranger's touch. Since it is proposed that the CT system is linked to the brain's emotional response system, the interpretation of a tactile stimulation is directly related to the personal connection and familiarity between the person who is touched and who touches. Therefore, when the mother is touched by the father, a familiar and close person, the neurophysiological and hormonal responses will be different compared to that of a stranger's touch, possibly influencing the fetal response due to the shared blood connection (Emory & Dieter, 2006; Monk, Fifer, Myers, & Sloan, 2000; Pluess, Bolten, Pirke, & Hellhammer, 2010; Skouteris, Wertheim, Rallis, Milgrom, & Paxton, 2009; Talge et al., 2007).

Development and importance of movements

Newborn infants' capabilities of engaging with the world are dependent upon their capacity for prospective sensorimotor activity, meaning their ability to direct movements prospectively by incorporating an anticipatory structure which is engaged towards a future consequence (Lee, 2005). The degree to which an infant is capable of performing a complex action is dependent upon its prospective planning and control capacity, which begins early during development, well before birth (Einspieler, Prayer, & Prechtl, 2012). During the end of embryogenesis, at 7 wGA (Einspieler et al., 2012), first embryonic movements can be observed by ultrasound (de Vries et al., 1982; H. F. R. Prechtl, 1990). These movements are self-generated and spontaneous, such as movements of the rump, head, or both by 7wGA and 2 days (de Vries et al., 1982; Prechtl, 1990), which are followed by small discernible movements of the trunk, arms, and legs (Lüchinger, Hadders-Algra, van Kan, & de Vries, 2008). Further movements can be observed from 8wGA, such as displacements and rotations of the thorax, head movements, as well as movements of the limbs, also referred to as general movements (de Vries et al., 1982; Piontelli, 2010). Early fetal movements create biomechanical forces of momentum and inertia across the whole body via opposing reciprocal forces, which gives rise to the opportunity of neuromotor learning as a consequence of action. These movements form the basis of future complex motor movements which require whole body control and coordination. Established movements form the embodied foundation for future learning of incorporating sensory consequences to external circumstances, and are part of the process of learning from prospective actions over developing sensorimotor intentionality, which begins during fetal development (Delafield-Butt & Gangopadhyay, 2013).

During late embryogenesis movement and fetal growth are crucial for biological development, since a variety of consequences can result from lack of movement and growth. Animal studies have demonstrated the importance of neuromotor system tuning through apoptosis, motor axon guidance, motor endplate formation, normal distribution of neurotransmitter receptors on muscle fibres, population of spinal motor neurons, and neuromuscular synaptic contacts (Benoit & Changeux, 1975; Hanson & Landmesser, 2004; Harris, 1981; Usiak & Landmesser, 1999). Movement is important during organogenesis to prevent adhesion and epigenetic regulations of the fetus (Visser & Prechtl, 1988), as the failure to move in utero can result in fatal consequences as it can result in various deformations related to the Pena-Shokeir phenotype, which usually results in death in utero (Hall, 2009).

Early fetal movements serve a variety of psychological and biological mechanisms from adjusting neural connectivity and tissue growth as well as creating first experiences of learning as is evident in the brainstem (Winn, 2012). Observed fetal movement patterns have been reported to confirm continuity of agency related to the individual, as previous observations revealed idiosyncratic behavioural consistencies between prepartum and postpartum life (Piontelli, 1992; 2002). A possible idiosyncratic behavioural consistency between pre-and post-partum life are fetal movements and childhood ‘play’, which are suggested to show the functional continuity of play (Bekoff, Byers, & Bekoff, 1980). Fetal actions are reasoned to be both functional and adaptive for the fetus in relation to its preparation for the post-partum environment (Oppenheim, 1981).

This coordinated movement readiness involving cognitive processes dealing with an increased environmental complexity of motor, memory, planning, and perceptual demands on the newborn, is unlikely to have arisen only postpartum, but rather during the development before birth, and continues refining throughout the infants’ development.

The newborns’ ability to master its responsive environment, using anticipatory motor engagement, the sensorimotor intentionality of prospective, and psychomotor foundation of cognitive agency, underlies a basic prospective control of movement, which develops before birth and underpins the mind-body unity of the newborn which is made possible by its neuro-motor physiological development.

As previously indicated, the mother is a special source of somatosensory stimulation during fetal development. Mothers automatically engage in abdominal tactile stimulation, ‘rubbing their bellies’ in order to feel, to calm, to stimulate, or to interact with the fetus. While the mother stimulates the abdomen externally, it is also accompanied by internal muscular and skeletal body movements of the mother. This abdominal stimulation exerts a slight pressure, and as a result, the abdomen, including the uterine environment move and thus, passively stimulate and touch the fetus. Such stimulation is often related to the mental and emotional state of the mother. External tactile stimulation of the maternal abdomen can also occur through fathers or strangers’, or sometimes object stimulation. Although maternal touching of the abdomen during pregnancy is a very common indirect sensory-motor tactile stimulation affecting the fetus, it has been scarcely studied before our recent research (Marx & Nagy, 2015). Research in the field of behavioural fetal psychology, such as on the effects of maternal touch on the fetus, and how the fetus responds to touch is a relatively recent stream of interest and has been made possible by the introduction of ultrasound (Reissland & Hopkins, 2010).

Earliest studies examined fetal movements using 2D, black and white, ultrasound (de Vries et al., 1982; 1985; 1988; Prechtl, 1985). Current research, however, is capable of examining fetal behaviour using 4D ultrasound, showing three-dimensional moving real-time images of the fetus, in a much higher resolution which allows not only visualise the fetus and its environment in more detail (i.e. facial features) but also increases the possibilities of observing fetal behaviours and responses to external stimulation in a much clearer way than before when only 2D ultrasound was available (Kisilevsky et al., 2012; Marx & Nagy, 2015; Reissland et al., 2012; 2013).

Even with the aid of the ultrasound, most early research focussed on fetal heart rate (FHR) measurements for their dependent variables as the analysis of ultrasound footage is a time-consuming procedure which involves an extensive amount of training regarding the analysis of the ultrasound footage. FHR measurements are more easily processable and less time consuming and has thus been rather popular in the field of fetal psychology. Unfortunately, the use of FHR measurements has not been the most stable measurement across studies (Kisilevsky et al., 2003; Kisilevsky & Hains, 2010).

Kisilevsky, Muir & Low (1992) investigated fetal responses to mechanic vibroacoustic stimulation fetuses (23-36 weeks GA). Findings suggest that between 26-28 weeks GA small FHR decreases occur which are followed by FHR accelerations. From 29 weeks GA, most fetuses responded with a FHR acceleration of 10 bpm to the vibrations (Kisilevsky et al., 1992). It was also observed that older fetuses (26-36 weeks GA) increased movement responses to vibrations (Kisilevsky et al., 2012). Overall it was concluded that from 26 weeks GA fetal responses increase steadily reaching maturity around 32 weeks GA. Further research interested in fetal movements and observed that fetuses open their mouth in anticipation to the hands touching the lips, suggests knowledge of the intersensorimotor body relationship between 19-35 wGA (Myowa-Yamakoshi & Takeshita, 2006).

Anecdotal observations propose that in early pregnancy fetuses tend to move away from stimuli touching their bodies, whereas later in gestation fetuses tend to move towards the source of stimulation (Hooker, 1952; Valman & Pearson, 1980). In relation to this, our previous research examined fetal responses to the mother's touch of the abdomen. Fetal responses were compared between maternal touch and live voice and revealed more arm, head, and mouth movements to the mother's touch compared to the mother's voice at 21-25 wGA (Marx & Nagy, 2015). These findings show that the fetus responds to maternal touch and prompts the question whether the fetus responds differently to tactile stimuli of different origin.

Aims of Experiment 2

The aim of Experiment 2 was to first confirm whether fetuses respond to the touching of the mother's abdomen and if they do, whether they differentiate based on the familiarity and the source of the touch.

There are anecdotal observations that during early pregnancy fetuses tend to move away from stimuli that touch their bodies, whereas later they tend to move towards the stimulation (Hooker, 1952; Valman & Pearson, 1980). Based on the background literature (Kisilevsky et al., 1992; 2012; Myowa-Yamakoshi & Takeshita, 2006) and our previous study (Marx & Nagy, 2015), it is expected that fetuses respond to the tactile stimulation with increasing movement, especially later in pregnancy, in the third-trimester. Our previous research (Marx & Nagy, 2015) suggests that the fetuses displayed an arousal response to maternal 'tactile stimulation' that is when the mother was touching her abdomen. Fetuses increased their arm, mouth and head movements when the mother touched the abdomen compared to when the mother just spoke or did nothing in a control condition.

Aim 1: Responses to tactile stimulation

The present study aims to compare fetal behavioural responses to different types of abdominal touch: when the mother, the father, and a stranger touches the maternal abdomen, and a control (no-touch, silent) condition. The rationale of the design of the four conditions is the following: When the mother is touching her abdomen, the stimulation is not only familiar to the fetus (given the mother touched her abdomen numerous times during pregnancy) but is also congruent with the movement that accompanies the familiar maternal abdominal touch. Not only is the mother's external touch likely to be familiar to the fetus but is also combined with internal movements, stimulating the fetus further. For the external stimulation two tactile sources were chosen, the touch of the father and of a stranger. There were several reasons for including two additional external sources of stimulation. A stranger was included as strangers are commonly used to compare a mothers' in psychological experiments. Although experiments with fetuses, newborns and infants included strangers, a stranger has not yet been included in any tactile experiments of the fetus (DeCasper & Fifer, 1980; Kisilevsky et al., 2003). Having a stranger touch the maternal abdomen will stimulate the fetus externally. It is important to take into consideration that a stranger to the fetus is also a stranger to the mother, as opposed to when a father or partner touches the maternal abdomen.

In comparison, a familiar touch, namely the father's touch, was included because the father's touch is likely to be familiar to the fetus. The nature of the pressure is entirely external and is not accompanied by internal congruent movements of the mother, who lies still while the father is touching her abdomen. When the stranger touches the mothers' abdomen, the touch is also external but also, unfamiliar. This allows examining whether there is indeed a difference between the fetal reactions to an external tactile stimulus overall, preference for familiarity and a preference for the touch of the mother. The main aim, therefore, is to explore if the fetus is capable of discriminating between the touches.

Only the fetal response can indicate whether the response to the mother is significantly different to that of external stimulation and whether the response to external stimulation is different or the same for the father and stranger. If it is different it is likely that the fetus is capable of discriminating between the touch styles and/or who is touching if we consider the mother's state (i.e. heart rate levels), as the touch of an unfamiliar stranger is likely to increase the mother’s heart rate compared to the father’s touch.

Hypothesis 1a: It is hypothesised that fetuses will respond differentially between mothers’ touch and control condition, which involves no touch.

Hypothesis 1b: It is hypothesised that there will be more externally directed movements instead of self-directed movements, such as fetuses hands touching the uterus or pressing their face against the uterine abdominal wall when the mother touches the abdomen compared to control and the other two tactile stimulations if mother’s touch has unique properties.

Hypothesis 1c: We expect to find increased arm movements and head movements during maternal stimulation compared to the control condition.

Hypothesis 2: H2 will examine if fetuses respond to tactile stimulation overall (regardless of who touches the mother’s abdomen) compared to the control condition with no touch. Specifically, it is expected that there will be increases in movements to the external stimulation, possible differences in the intensity of the response between mother, father, and stranger if the fetus is capable of discriminating between touches.

Hypothesis 3: H3 will examine whether fetuses are capable of responding differently to father's and stranger's touch. Although the familiarity will be different between the touch of the father and the stranger, the experiment will use calibration to ensure the safety of the tactile stimulation on the maternal abdomen to ensure that the touch is not very dissimilar in terms of pressure compared to how the mother touches.

Aim 2: Maturational differences

The fetus is still developing throughout both trimesters. However, throughout the second-trimester fetal neurodevelopment and physiological development progress quickly allowing the fetus to sense and react to early stimulation (Garel et al., 2001; Huang, 2009). By the third-trimester, the fetal neurodevelopment has advanced further and should resemble that of a premature neonate more, as senses have matured further preparing the fetus for external (ex-utero) life (Huang et al., 2006). It is therefore of importance as the second main aim of Experiment 2 to take the developmental level of the fetus into account and expecting a stronger response in the more neurologically mature third-trimester fetuses compared to the second-trimester fetuses, as our previously published research has indicated maturational differences in behavioural responses (Marx & Nagy, 2015).

Hypothesis 4a: It is hypothesised that there will be differences between second- and third-trimester fetuses, due to a more matured CNS. Specifically, more differentiated responses related to the source of the stimulus in the third-trimester compared to the second trimester. As our previous study (Marx & Nagy, 2015) has indicated differences between second- and third-trimester fetuses, we expect these differences to persist in this experiment. Responses appeared to be more structured and stronger for third-trimester fetuses, thus it is expected that we will find similar responses in this experiment.

Hypothesis 4b: It is hypothesised that third-trimester fetuses are likely to differentiate the touch of the mother compared to the no-touch condition.

Hypothesis 4c: It is hypothesised that third-trimester fetuses show a stronger differentiation to the tactile stimulation overall compared to no-touch compared to second-trimester fetuses.

Hypothesis 4d: It is further hypothesised that older, third-trimester fetuses differentiate between the touch of the father and the stranger. It is expected to find stronger behavioural responses to the father's touch compared to the stranger's touch in third, compared to second-trimester fetuses.

Aim 3: Time interval analysis and detailed coding system

The third aim is to measure the behavioural responses with a detailed coding system that is specifically designed to monitor the available movement repertoire of the fetus, with frame-by-frame analysis to explore the fetal behavioural responses further. Previous literature has often examined general movements instead of individual movements, which possibly results in the loss of reactions depending on the analytical approach used (Shahidullah et al., 2007). Thus this coding system focuses on subjective individual movements and touch localisations such as an arm, head, and mouth movements; different types of localisations for touch (own body/face/uterus), positions of arms crossed and hands crossed, and yawning. For the purpose of further analyses, the coded variables have been reduced into four groups, general movements, self-touch, external touch, and inactivity/resting. This coding system is based on a previously developed and trialed coding system from our previous study (Marx & Nagy, 2015) and will be utilised for the purpose of the current study.

Moreover, not only the coding system needs to be fine-grained but also the temporal resolution of the analyses, by using different temporal windows to investigate how the responses appear and evolve over time.

Hypothesis 5: In addition to the main analyses, we would like to examine the fetal behavioural responses over different time intervals. Averaging the results over a two-minute period would statistically average out important changes which occur over the course of the stimulation. Thus a further aim of this study is to examine the first 10 and 15 seconds post onset of the stimulus. We would also like to examine the two-minute stimulation broken down in the first and second minute of stimulation. The literature mainly focusses on the first minute of stimulation (Kisilevsky et al., 2003; Lee & Kisilevsky, 2013), thus we will continue focusing our work on the first minute of stimulation too in order to have comparable results, but we would also like to examine the following minute of stimulation (60-120s) and additionally break the two minute intervals down in to 30s segments in order to gain a more detailed insight into sequenced movement responses over time.

Methods

Design

The experiment employed a 4x2x2 mixed experimental design, where the independent variable had four within-subject levels: mothers touch, fathers touch, strangers touch, and no stimulation (control). The two levels of between-subjects factors of this experiment were gestational age in weeks (second ≤ 27 wGA or third-trimester >27 wGA) (see Figure 3a).

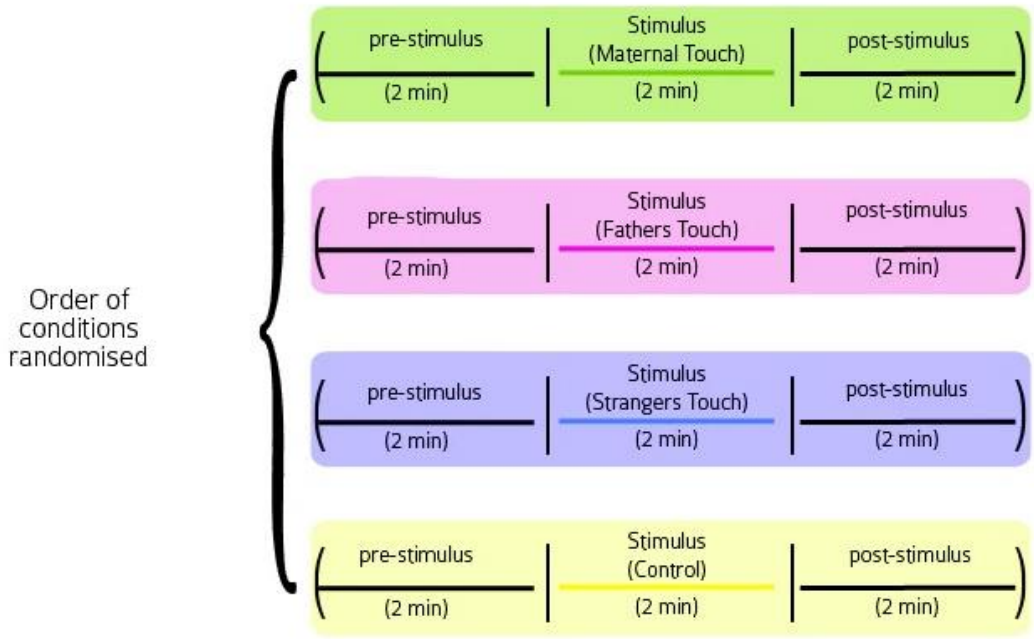

Figure 3a. Experimental procedure overview. All conditions were randomised both within and between participants. Each condition lasted 6 minutes in total, with 2 minutes per subsection (pre-stimulus, stimulus, post-stimulus). During pre- and post-stimulus sections of the experimental conditions, no stimulation occurred.

Participants

28 Mothers with low-risk singleton pregnancies in their 20-35 gestational weeks (Mean = 26.64 weeks, SD = 4.79) took part in the study. All mothers were native English speakers and live in Scotland. Participants were recruited through word of mouth and local Facebook baby groups for mother's to be in Dundee. 15 fetuses were in the second-trimester ('younger' fetuses ≤ 27

gestational weeks) and 13 in the third-trimester (‘older’ fetuses >27 gestational weeks).

Mothers were 18 - 35 years old (Mean = 26.64, SD = 4.73), with a normal BMI before pregnancy. None of the mothers reported a history of drinking, smoking or use of drugs during the pregnancy and all had the 20-week scan completed confirming that the development and the health of the fetus as well as the pregnancy had no known complications.

Time of gestation was chosen as the fetus has already developed its major organs and senses by then. At this age, fetuses are able to hear the mother’s voice and feel the touch or pressure via her abdomen (Kisilevsky et al., 1992; Shahidullah et al., 2007). From that age, fetuses will mainly continue to grow in size and develop further. This also means that the minimal risk of possible harm to the fetus during the study. Finally, between the gestational ages of 21-35, the fetus is an ideal size to perform the 3D/4D ultrasound scan, as the intrauterine circumstances regarding amniotic fluid levels and fetal positions are ideal in order to achieve a high-quality picture.

All mothers signed the informed consent prior participation and the study was approved by the ethics committee of the University of Dundee (No. UREC 15068).

Materials

Participants information sheet and consent form (see Appendices 5 and 6) were used in order to obtain participants written consent to participate in this second experiment. Participants’ written consent was obtained for being recorded via video camera to allow for later synchronisation of the touch stimuli and the obtained ultrasound scan. Also, permission for the use of imagery for publication and illustration purposes was obtained from participating mothers.

Demographic questions

A demographic questionnaire (see Appendix 7) was administered consisting of questions regarding age, gestational week, marital status, number of dependents, education, the health status of mother and fetus, smoking during and prior pregnancy, attendance at antenatal classes. Participants were required to indicate time spent engaging with the baby by (1) talking to the baby and (2) touching the bump by oneself/father/ other family members/strangers measured in hours per day.

Beck's Depression Inventory

To measure maternal mental health as background information, the Beck Depression Inventory (BDI) (Beck et al., 1961) was administered to assess expecting mothers' current level of depressive symptoms. This self-reported paper-and-pencil based questionnaire consists of 21 items. Items consist of a possible choice of four answers of which the participant has to select the most suitable characteristic at the time of responding. For example as in item 1: 1) I do not feel sad, 2) I feel sad, 3) I am sad all the time and can't snap out of it, 4) I am so sad or unhappy that I can't stand it. Items are scored from 0-3 and added together for a summary score. The minimum summary score is 0 and the maximum score is 63.

Antenatal Maternal Attachment Scale

A second background maternal measure was the Antenatal Maternal Attachment Scale (AMAS) (Condon, 1993), a 19 item self-reported paper-and-pencil questionnaire on maternal thoughts and feelings of the developing baby was included to assess maternal-fetal attachment was administered. The AMAS measures three factors such as quality of attachment, time spent in attachment mode (or intensity of preoccupation) and a global attachment score. Items investigating the time spent in attachment mode are statements such as "Over the past two weeks I have found myself talking to my baby when I am alone". Possible answers to this item are "not at all", "occasionally", "frequently", "very frequently”, and “almost all the time I am alone”. An example for an item exploring the quality of attachment is “When my baby is born I would like to hold the baby” with answers being “immediately”, “after it has been wrapped in a blanket”, “after it has been washed”, “after a few hours for things to settle down”, and “the next day”. This questionnaire was selected, as it is a common questionnaire to assess the maternal-fetal relationship. The results from the AMAS were scored using the key provided with the questionnaire.

Ultrasound methodology

A 'GE Voluson e' Ultrasound System with 'RAB4-8-RS4D' probe and water-based conductive ultrasound gel was used to perform the 4D ultrasound scan. The scan was recorded on an Apple 'MacBook Pro’ (13 inches, MBP7,1 MC375xx/A) laptop using 'Game Capture HD' software for 'MAC OS X' from Elgato. The laptop was connected to a high definition game recorder, 'Elgato Game Capture HD', which was connected to the ‘Voluson e’ via VGA to HDMI converter. The signal, via the 'Elgato Game Capture HD', was sent to a 22inch widescreen LCD monitor (DGM L-2254WD) positioned at the end of the scanning bed on a table, which allowed the participants to follow the scan comfortably. A 'Sony HDR CX220E’ camera mounted on a tripod was used to record both video and audio of the mothers’, fathers’, and stranger’s behaviours framing the participants’ face and stomach, to capture tactile stimulation, including the screen of ultrasound system to allow for later synchronization during analysis if it was needed.

Procedure

The experiment took place in the morning hours in a semi-darkened room of the Developmental Neuropsychological laboratory of the School of Psychology at the University of Dundee. Participants were presented with the participant information sheet that described the procedure in detail, a consent form, and after signing the informed consent, a demographic questionnaire was administered prior to the scan. Participants received no incentive other than a free scan and a copy of the scan on DVD for their participation.

Touch stimulus Calibration

This experiment aimed at stimulating the fetus via touching the mother's abdomen by the mother, father, and stranger and comparing these conditions to a control, no-touch condition.

The touch was 'calibrated' prior to the experiment in order to ensure the safety of the touch and in some extent that the tactile stimulation was safe and more similar to the pressure and the nature of the touch the mother provides and not massive rubbing, push or uncomfortable stimulation. Mothers were asked to lie on their backs on the scanning bed, using a pillow behind their head to achieve a comfortable scanning position and then to touch/rub their abdomen as she would naturally do. The father and the stranger observed the positioning and movement of the touch. The mother also verbally explained how she was normally 'stroking' her abdomen. Following the mother's stimulation, the father and the stranger were asked to touch the mother's abdomen the same way and the mother provided feedback on the movement and the pressure.

The experimenter conducting the scan sat next to the scanning bed. Before the experiment began, the state and the position of the fetus was assessed utilizing 2D ultrasound. Depending on the fetal position, whenever it was possible 4D scan was administered. During the scan, depending on fetal movements and rotation 4D might have been dispensed and a 2D scan was administered until further 4D acquisition was possible. Fetal movements can be visualised during both acquisition types, however, are much clearer in 4D thus 4D was the preferred method and 2D was only utilised when 4D was not possible. Therefore, the fetus could be observed throughout the experiment without any interruptions. The acquisition window framed the fetal head and upper torso including face, and arms/ hands at all times.

The experiments consisted of four within-subjects' conditions (see Figure 3a). Participants were scanned for two minutes without any stimulation in complete silence (pre-stimulus), which was followed by two minutes of stimulation (tactile stimulation by the mother, father, stranger) and ended with two minutes of no stimulation (post-stimulus). During the control condition participants were scanned for 6 minutes without stimulation. The total scanning time was 24 minutes.

All conditions were counterbalanced and randomized across participants. Participants received a non-verbal signal from the stranger, who monitored the start and stop times with a stopwatch. Between conditions, the mothers were given a short break before the experiment resumed with the next condition. Following the scan, mothers had to complete the AMAS (Condon, 1993)as well as the BDI (Beck et al., 1961). Fathers were asked to complete an altered version of the AMAS (Condon, 1993).

Coding and coding system

The behaviour of the fetuses was coded using frame-by-frame coding with the Noldus Observer System (*The Observer 5.0 Reference Manual*, 2003). After initial explorations of the scans, a coding system was designed that consisted of 20 variables such as arm movements, head movements, mouth movements, hands touching the body/face/uterus, arms crossed, and yawning. Both frequencies and the duration of the movements were coded and analysed by the Observer system.

Fetal touch was divided into self-touch of the own body (‘Body touch’), self-touch of the face (‘Face touch’) and touching of the uterine environment (‘Uterus touch’). Furthermore, the touching of the uterus with the fetal face (‘Face press’) was coded. ‘Body touch’ included the fetus touching its body with its hands but not the face, which was coded separately. ‘Face touch’ describes the fetus touching its head including the face with one or both hands. ‘Uterus touch’ was coded when fetus touched the uterine wall or placenta with either hand or both.

Two common positions of the arms and hands were coded. ’Arms-crossed’ describe the crossing of the arms in front of the body or the face.

‘Hands-crossed’ was coded when the hands were in front of the face and the fists were touching one another. ‘Hand movements’ were coded when the hands moved other than crossing, and isolated ‘Finger movements’ were also coded. Body ‘Rotation’ was coded when the body of the fetus was visibly turning towards or away from the probe.

‘Mouth movements’ were coded when the fetus was opening and closing its mouth, while ‘Yawning’ was a separate code. ‘Tongue protrusion’ was coded when the fetus stuck its tongue out. ‘Sucking’ was coded when the repetitive mouth and lip movements were observed. ‘Hiccups’ were coded when the intercostal muscles and diaphragm contracted accompanied by jerky movements. Fetal ‘Breathing’ was coded when repetitive inward movements of the chest wall were observed accompanied by a simultaneous outward movement of the abdominal wall. Fetal ‘Stretch’ was coded when the fetus erected, stretched its torso and tilted its head backward and this movement lasted for longer than 2 seconds.

Finally, fetal ‘Kicking’ of the legs was coded when it was visible, although often the legs were not visible from the scanning window.

In order to further examine the nature of fetal behavioural responses, movements were grouped into further variables. As the literature tends to examine fetal general body movements (Shahidullah et al., 2007) instead of detailed body movements thus ‘Arm’ and ‘Head movements’ were combined to represent ‘General movements’.

Furthermore, different types of touch were combined in order to reflect either externally directed touch or self-aimed touch. ‘Body touch’ and ‘Face touch’ were calculated to represent ‘Self-touch’. ‘Uterus touch’ and ‘Face press’ were calculated to represent ‘External touch’. Lastly, ‘Arms-crossed’ and ‘Hands-crossed’ were combined in order to represent fetal ‘Inactivity/Resting’ since these movements are very similar as they only vary in hand/arm positioning but generally involve the fetus being still.

An overview of the coded variables and brief descriptions can be found in Table 3a and 3b for the combined variables.

Table 3a. Coding system developed to analyse fetal movements in utero. All original variables and breakdown of variables for hierarchal variables with descriptions displayed.

Variable Name	**Breakdown of Variables**	**Description**
Arm Movements	Starts/Stops	Any visible arm movements
Touch (hierarchal)	Own body	Fetus touches its own body with hand(s), everything apart from the face
	Face	Fetus touches its own face with hand(s)
	Hands-Uterus	Fetus touches the uterine wall with hand(s)
	Stop	Fetus lifts hand off body/face/uterus wall and stops touching
Hands-crossed	Starts/Stops	Fetus makes two fists, which touch each other with the side of the palms
Arms-crossed	Starts/Stops	Arms are crossed over the body, also touching at the interception
Body turning	Starts/Stops	The whole body is turning away/towards the probe
Hiccup	Starts/Stops	quick jerk, starting in the upper torso
Yawning	Starts/Stops	Long opening of the mouth often accompanied by tilting the head backward
Mouth Movements	Starts/Stops	The mouth opens, lips part, and closes, lips back together

Tongue Movements (hierarchal)	Out	Tongue out of the mouth
	Moving in mouth	Only visible in 2D, the tongue is moving in mouth not coming out
	Stops	Tongue stops any movements
Sucking	Starts/Stops	Repetitive mouth, lip and tongue movements resulting in sucking movements
Breathing	Starts/Stops	Fetal breathing is described as an inward movement of the chest wall along with an outward movement of the abdominal wall
Stretching	Starts/Stops	Stretching, back bending of the head for more than 2s including straightening of the spinal chord
Hand movements (hierarchal)	Hand movements	General hand movements such as rotations or up and down movements of the wrist
	Fist	Hand and fingers move to form a fist
	Finger Movements	Single/Multiple finger(s) are moving independently
	Stops	All hand/finger movements stop
Face press	Starts/Stops	Face touches uterus wall with forehead or larger facial area
Kicking, Event		If legs are visible, rapid sudden movements

Table 3b. Combined Variables. Combined variables are computed creating a total number of frequencies and total duration in seconds for each computed variable.

Variable Name	Combination of	Description
General Movements	Arm Movements Head Movements	Both, ‘Arm movements’ and ‘Head movements’ are generally referred to as gross body movements.
Self-touch	Body Touch Face Touch	Both, ‘Body’ and ‘Face touch’, are forms of tactile self-stimulation.
External touch	Uterus touch Face press	Both, ‘Uterus touch’ and ‘Face press’ involve the fetus touching the uterine wall.
Inactivity/Resting	Arms-crossed Hands-crossed	Both, ‘Arms-crossed’ and ‘Hands-crossed’, are positions where the fetus is not moving, but inactive/ in a resting position instead.

Scoring

Beck’s Depression Inventory

Scoring of the BDI (Beck et al., 1961) involves adding up scores of the 21 items. Items begin at 0 – with no depressive symptoms such as I do not feel sad, I do not feel like a failure, or I do not cry more than usual. The next level is 1 which represents answers such as the following: I feel sad, I feel I have failed more than the average person, and I cry more now than I used to. Statements scored with 2 points include the following: I am sad all the time and can't snap out of it, as I look back on my life, all I can see is a lot of failures, and I cry all the time now. 3 points represent the most severe depressive symptoms such as I am so sad or unhappy that I can't stand it, I feel I am a complete failure as a person, and I used to be able to cry, but now I can't even cry even though I want to. The total score of the 21 items relates to the levels of depression. These levels range from 1-10 which are ups and downs considered normal, 11-

16 mild mood disturbance, 17-20 borderline clinical depression, 21-30 moderate depression, 31-40 severe depression, and over 40 points it signifies extreme depression. According to the BDI a persistent, meaning if the test is done multiple times, a score of 17 or above indicates the need for professional treatment. The minimum score is 0 and the maximum score is 63.

Antenatal Maternal Attachment Scale

Scoring of the AMAS (Condon, 1993) involves scoring individual items using the scoring key. The questions are separated into two groups: Quality of attachment and time spent in attachment mode. Overall items are scored from 1-5, with 1 being a low attachment and 5 being a high attachment. Items in brackets are reversed scored. Items (3), (6), (9), (10), 11, (12), 13, (15), (16), and 19 are added up and load onto the quality of attachment, with a maximum score of 50. Items (1), 2, 4, (5), 8, 14, 17, and (18) are summed up in order to receive the score for time spent in attachment mode/intensity of preoccupation, with a maximum score of 40. Item 7 ("Over the past two weeks I have felt that the baby inside me is dependent on me for its well-being") does not load on either of the two factors, however, is included in the global attachment score, where its value is reversed. The global attachment score is calculated by summing the quality of attachment and time spent in attachment mode factors together with item 7 and the highest achievable score is 95.

Reliability coding of the behavioural data

11.2% of the entire dataset were reliability coded by a trained second coder. Inter-rater reliabilities for frequency ranged from 82.14% to 100% with an average of 92.27% and Cohen's Kappa ranged from 0.80 to 1.00 with an average of .91. Inter-rater reliabilities for duration ranged from 72.02% to 100% with an average of 91.98% and Cohen's Kappa ranged from 0.70 to 1.00 with an average of .92.

Results

All coded variables and combined variables were analysed. The reported results will include all significant results ($p < .05$) as well as tendencies ($p < .10 \geq .05$). Bonferroni corrections were applied for all post-hoc analyses. Although each stimulation/experimental condition lasted 2 minutes in total, this analysis attempted to examine the responses at various time intervals to further explore the evolvement of the responses over time. Only focussing on the whole 2-minute interval would disregard many sensitive findings which occur throughout the 2-minute period including the initial response and possible habituation to the stimulation. The 2-minute interval is of course included in the analysis, as significant results from this section should represent the strongest results of the conditions. The most common intervals chosen for the analysis of fetal responses focuses primarily on the first 1-2 minutes of stimulation (Kisilevsky et al., 1992; Shahidullah et al., 2007). Thus the analysis will include both the first minute of stimulation (0-60s), the succeeding minute (60-120s) and the entire 2 minutes of stimulation (0-120s).

More delicate responses like the initial response during the first 10-15 seconds of the stimulation are likely to be averaged out by a larger time interval analysis. Thus both 0-10 seconds and 0-15 seconds were included in the analysis. Furthermore, the experimental conditions were split into 30-second intervals in order to explore the evolvement of the behaviour throughout the conditions producing the following time intervals: 0-30 seconds, 30-60 seconds, 60-90 seconds, and 90-120 seconds. The breakdown of 30-second intervals allows us to examine the responses in smaller time-windows over the course of the experiment as previous research suggests that the fetal motor movements habituate quicker to external stimulation compared to fetal cardiac responses (Lecanuet et al., 1983; 1986; 1988). For an overview of the time interval breakdowns see Figure 3b.

Due to the length of analysis and the focus of the thesis, maternal mental health (BDI) and the attachment data (AMAS), although analysed, are not reported in this chapter.

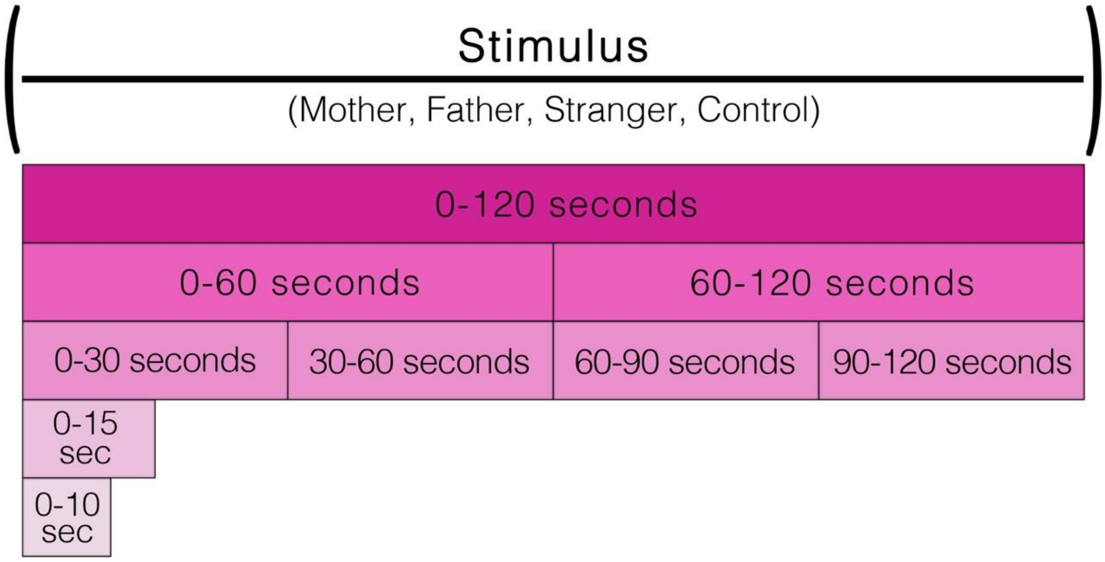

Figure 3b. Figure showing a breakdown of the created time sections for the interval analysis of the stimulation condition (0-120s, 0-60s, 60-120s, 0-30s, 30-60s, 60-90s, 90-120s, 0-15s, 0-10s).

0-10s Interval analysis

Repeated-measures ANOVA Condition: 'Arm movement' Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in 'Arm movement' frequency between the four Conditions (Control, Mother, Father, Stranger). Results showed a tendency between Conditions F (3, 81) = 2.39, p = .074, η_p^2 = .08. Examination of the means suggests that fetuses moved their arms differently between conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 6.88, p = .014, η_p^2 = .20. Overall, there is an increase produced by the means from 'Control' (M = 3.64) to 'Mother' (M = 7.50) and to 'Father' (M = 7.71). However, the 'Stranger' condition has a somewhat lower mean (M = 4.71) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.1). The means and standard errors can be examined in Table 3.1.

Table 3.1. Means and standard errors (SE) on the frequency of fetuses 'Arm movements' across conditions.

	Control	Mother	Father	Stranger
Mean	3.64	7.50	7.71	4.71
SE	1.04	1.59	1.51	1.17

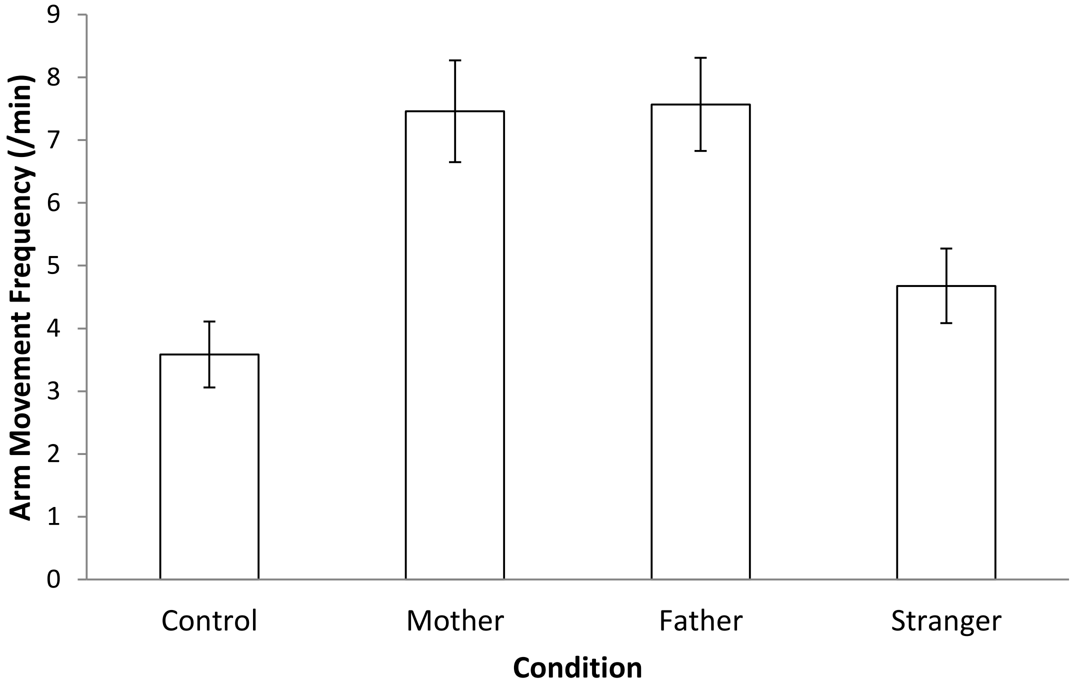

Figure 3.1. Average 'Arm movement' frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: 'Face press' Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the 'Face press' between the four Conditions (Control, Mother, Father, Stranger). Results showed a tendency between Conditions F (3, 81) = 2.27, p = .087, η_p^2 = .08. Examination of these means suggests that fetuses' 'Face press' frequency changed depending on Condition. Polynomial contrasts indicated, in support of this, that there was a significant quadratic trend, F (1, 27) = 6.35, p = .018, η_p^2 = .19. Overall, there is an increase produced by the means from 'Control' (M = 1.29) over 'Mother' (M =

1.93) to ‘Father’ (M = 2.79). However, the ‘Stranger’ condition has a somewhat lower mean (M = 1.71) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.2). The means and standard errors can be examined in Table 3.2.

Table 3.2. Means and standard errors (SE) on the frequency of fetuses ‘Face press’ against the uterus across conditions.

	Control	Mother	Father	Stranger
Mean	1.28	1.93	2.79	1.71
SE	0.47	0.54	0.58	0.52

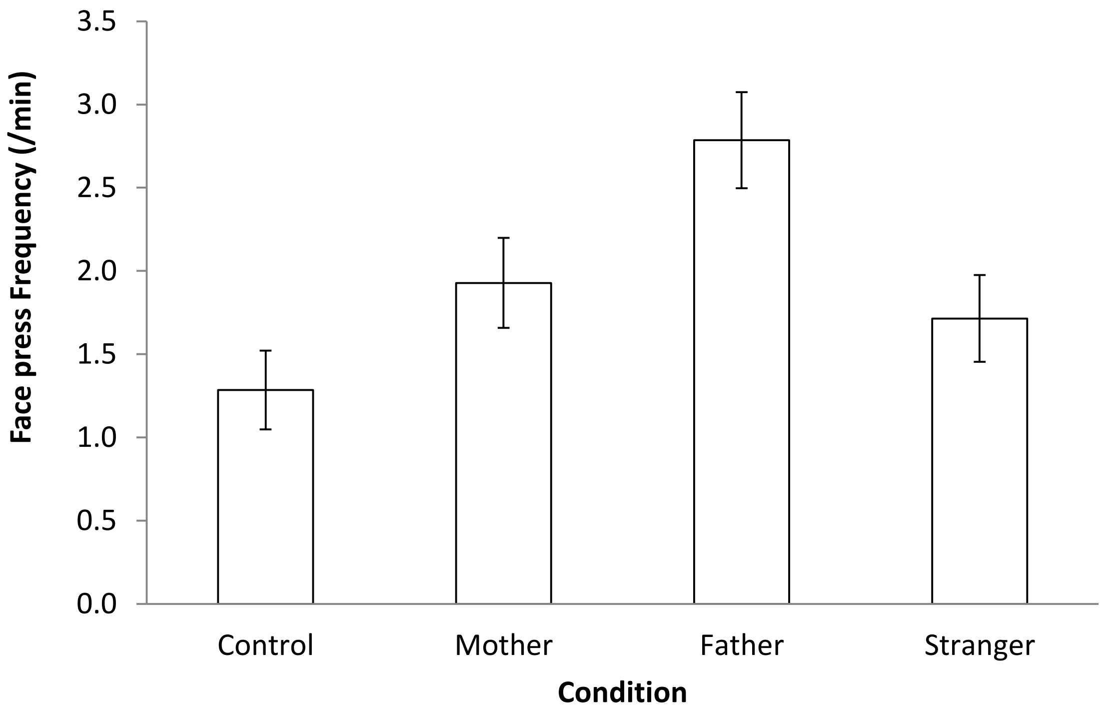

Figure 3.2. Average ‘Face press’ frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: 'Face press' Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in duration of the 'Face press' between the four Conditions (Control, Mother, Father, Stranger). Results indicate a tendency in 'Face press' duration between the four Conditions F (3, 81) = 2.27, p = .087, η_p^2 = .08. Examination of these means suggests that the 'Face press' duration differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant quadratic trend, F (1, 27) = 4.99, p = .034, η_p^2 = .16. Overall, there is an increase produced by the means from 'Control' (M = 21.43) to 'Mother' (M = 29.62), and 'Father' (M = 46.43). However, the 'Stranger' condition has a somewhat lower mean (M = 28.57) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.3). The means and standard errors can be examined in Table 3.3.

Table 3.3. Means and standard errors (SE) on the frequency of fetuses 'Face press' of the uterus across conditions.

	Control	Mother	Father	Stranger
Mean	21.43	26.62	46.43	28.57
SE	7.90	8.54	9.60	8.69

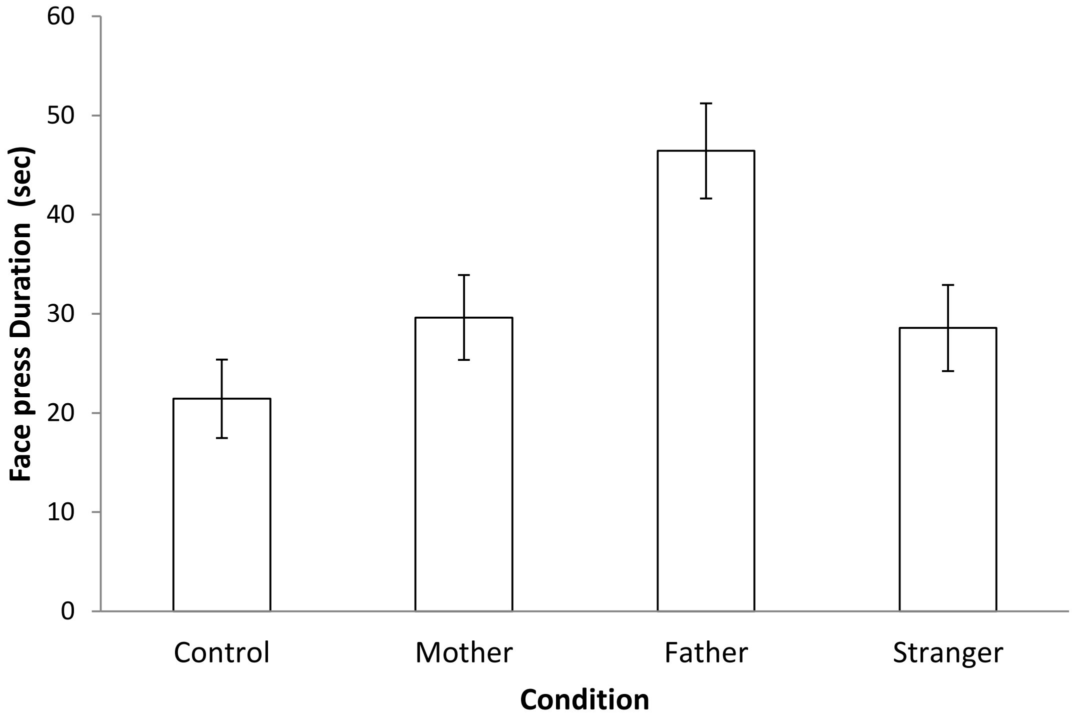

Figure 3.3. Average 'Face press' duration (seconds) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: 'Arm Movement' Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Arm movement'. The Condition main effect indicates a trend, *F* (3, 78) = 2.26, *p* = .088, η_p^2 = .08. No significant main effect of GA *F* (1, 26) = 1.87, *p* = .183, η_p^2 = .07, or an interaction *F* (3, 78) = 0.29, *p* = .834, η_p^2 = .01, were found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA *F* (1, 26) = 6.48, *p* = .017, η_p^2 = .20. Overall, there is an increase produced by the means from 'Control' (M = 3.59) to 'Mother' (M = 7.46), and 'Father' (M = 7.57). However, the 'Stranger' condition has a somewhat lower mean (M = 4.68) than producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.4). The means and standard errors can be examined in Table 3.4.

Table 3.4. Means and standard errors (SE) of fetuses 'Arm movement' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	6.80	0.97	4.85	1.05		
Control	4.40	1.43	2.77	1.54	3.59	1.05
Mother	8.00	2.21	6.92	2.38	7.46	1.62
Father	9.60	2.03	5.54	2.18	7.57	1.49
Stranger	5.20	1.62	4.15	1.74	4.68	1.19

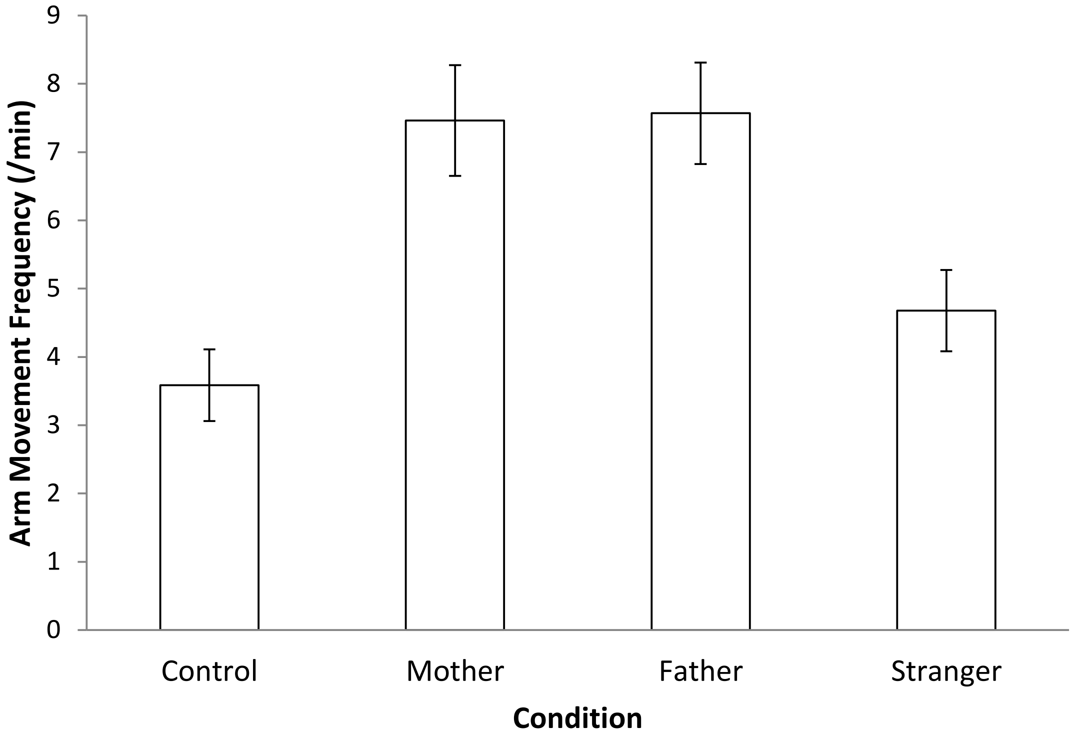

Figure 3.4. Average 'Arm movement' frequency (per minute) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: 'Arm Movement' Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Arm movement'. Results showed no significant main effects of Condition F (3, 78) = 0.93, p = .433, η_p^2 = .03, or an interaction F (3, 78) = 0.72, p = .540, η_p^2 = .03. However, a trend of the main effect of GA, F (1, 26) = 4.03, p = .055, η_p^2 = .13, was observed, showing that 'Arm movement' duration is dependent on GA.

Post-hoc pairwise comparison of the main effect of GA showed that younger fetuses (M = 26.79) tend to display prolonged 'Arm movement's (p = .055) compared to older fetuses (M = 16.26) (see Figure 3.5). No further effects were found. The means and standard errors can be examined in Table 3.5.

Table 3.5. Means and standard errors (SE) of fetuses 'Arm movement' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	26.79	3.57	16.26	3.84		
Control	26.50	8.12	11.61	8.72	19.05	5.96
Mother	34.59	8.45	18.39	9.08	26.49	6.20
Father	32.79	7.62	18.06	8.17	25.42	5.59
Stranger	13.26	5.48	16.99	5.89	15.13	4.02

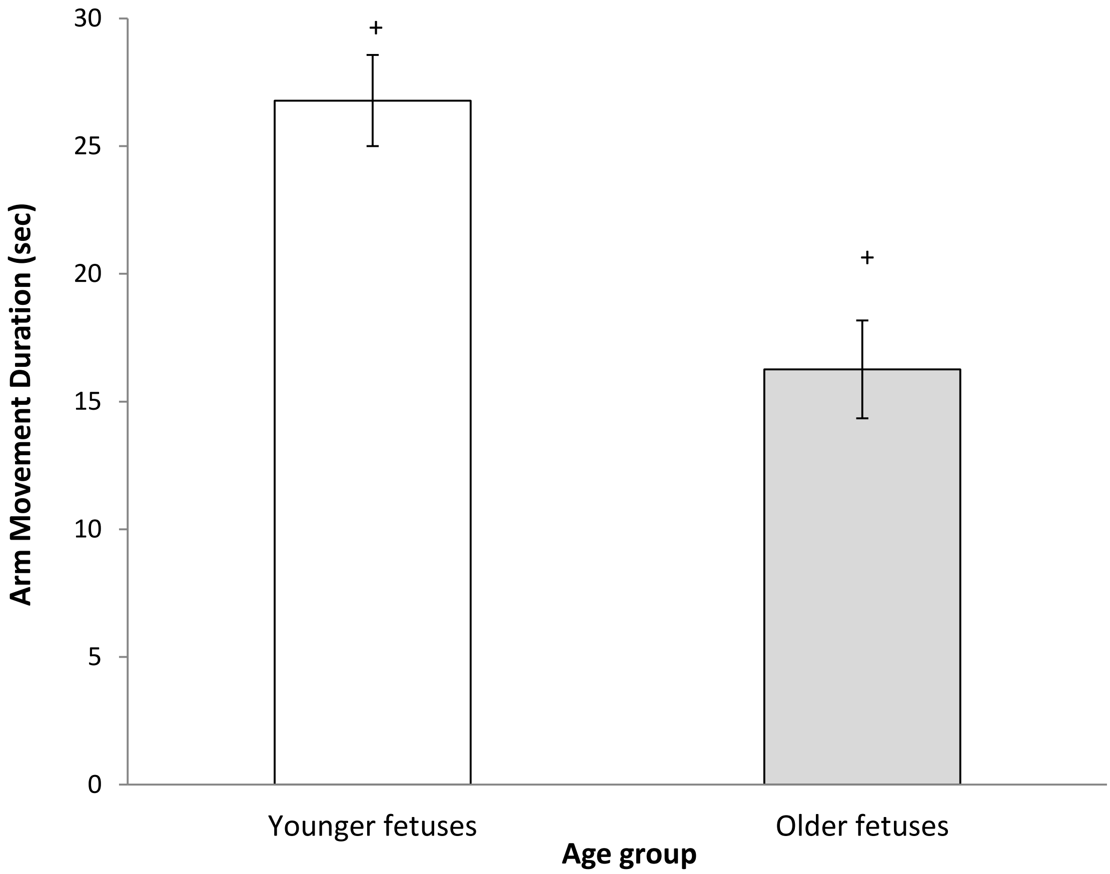

Figure 3.5. Average ‘Arm movement’ duration (in seconds) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Body touch’ Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Body touch’. Results showed no main effect of Condition F (3, 78) = 0.76, p = .519, $\eta_p^2 = .03$, and no significant main effect of GA F (1, 26) = 0.07, p = .798, $\eta_p^2 < .001$ but a tendency for an interaction between Condition and GA, F (3, 78) = 2.62, p = .057, η_p^2 = .09, was found. In support of this polynomial contrasts of the interaction show a significant quadratic trend of Condition and GA F (1, 26) = 4.94, p = .035, $\eta_p^2 = .16$.

Post-hoc pairwise comparison of the interaction between Condition and GA showed a tendency in ‘Control’ (p = .081), with older fetuses (M = 3.69) touching the body more compared to younger fetuses (M = 1.20).

Older fetuses decreased touch during maternal touch (M = 0.46) compared to ‘Control’ (M = 3.69, *p* = 0.64) but there was no difference in younger fetuses (see Figures 3.6 and 3.7). No further effects were found. The means and standard errors can be examined in Table 3.6.

Table 3.6. Means and standard errors (SE) of fetuses ‘Body touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.90	.045	1.73	0.48		
Control	1.20	0.94	3.96	1.01	2.45	0.69
Mother	2.00	0.82	0.46	0.67	1.23	0.46
Father	2.40	0.82	0.92	0.88	1.66	0.60
Stranger	2.00	0.87	1.85	0.93	1.92	0.64

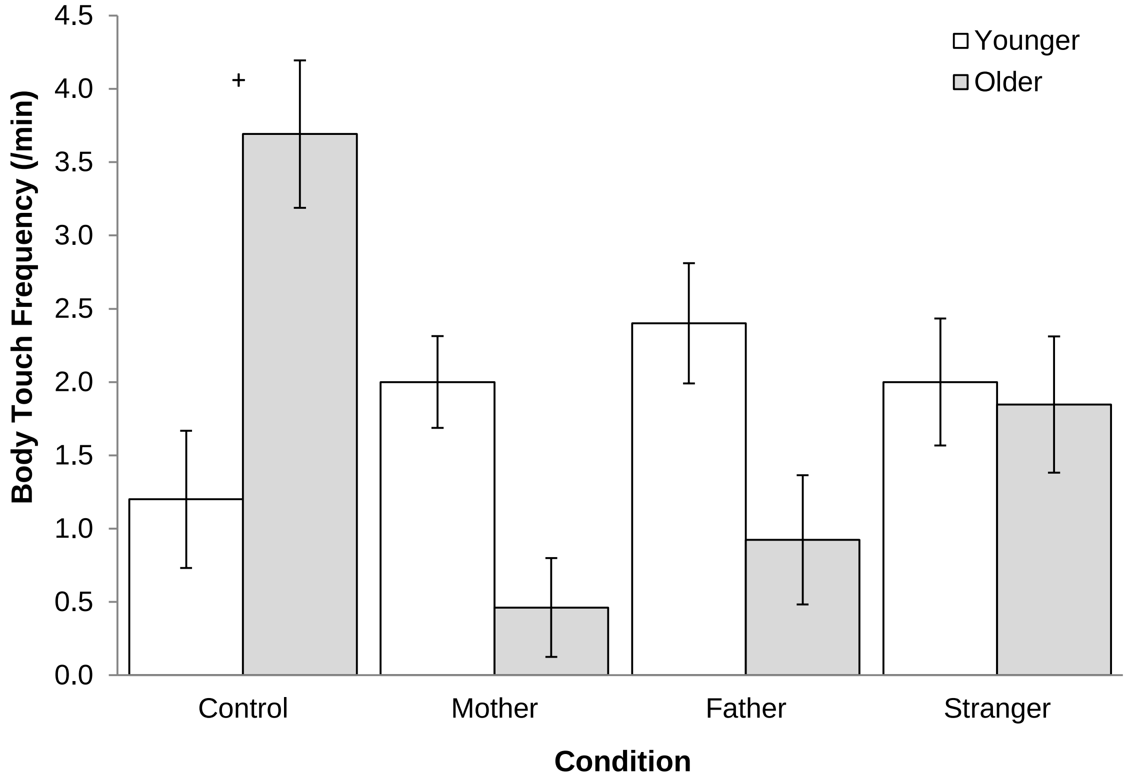

Figure 3.6. Average ‘Body touch’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

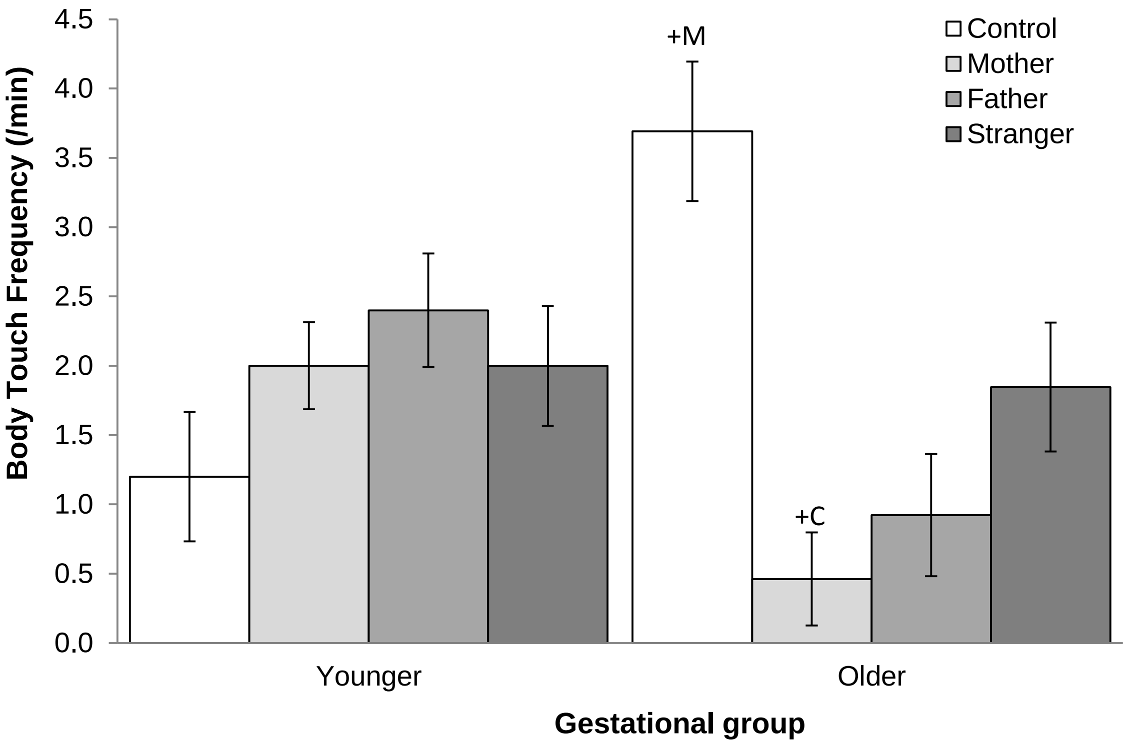

Figure 3.7. Average ‘Body touch’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Arms-crossed' Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Arms-crossed'. Results indicate a trend for a main effect of GA, F (1, 26) = 3.59, p = .069, η_p^2 = .12. No main effect of Condition F (3, 78) = 1.98 p = .124, η_p^2 = .07, or an interaction F (3, 78) = 0.60, p = .615, η_p^2 = .02, were found.

Post-hoc pairwise comparison of the main effect of GA showed a tendency (p = .069) for older fetuses (M = 1.73) to display more 'Arms-crossed' compared to younger fetuses (M = 0.80) (see Figure 3.8). No further effects were found. The means and standard errors can be examined in Table 3.7.

Table 3.7. Means and standard errors (SE) of fetuses 'Arms-crossed' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.80	0.34	1.73	0.36		
Control	1.20	0.84	2.77	0.90	1.99	0.62
Mother	0.40	0.41	0.46	0.45	0.43	0.30
Father	0.80	0.61	1.39	0.66	1.09	0.45
Stranger	0.80	0.67	2.31	0.72	1.55	0.49

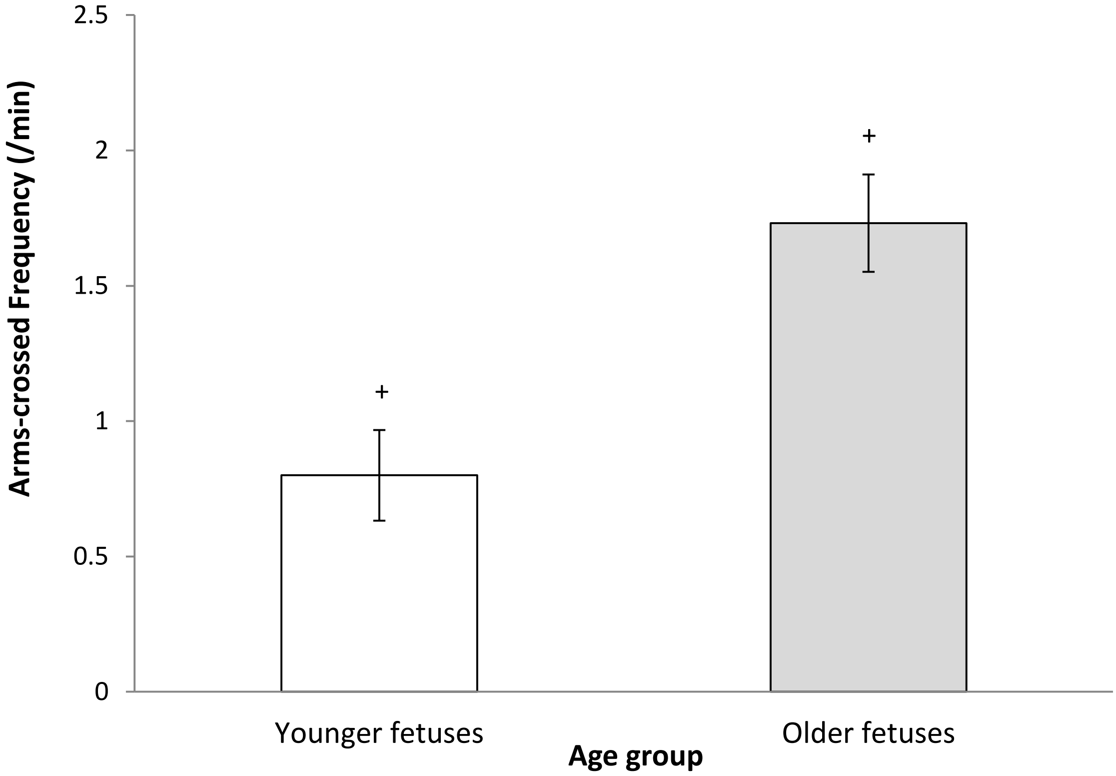

Figure 3.8. Average ‘Arms-crossed’ frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Arms-crossed’ Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Arms-crossed’. Results indicate a significant main effect of GA, F (1, 26) = 6.06, p = .021, η_p^2 = .19. No main effect of Condition F (3, 78) = 1.60 p = .196, η_p^2 = .03, or an interaction F (3, 78) = 0.89, p = .451, η_p^2 = .03, were found.

Post-hoc pairwise comparison of the main effect of GA showed older fetuses (M = 26.09) displayed significantly (p = .021) longer ‘Arms-crossed’ behaviour compared to younger fetuses (M = 8.23) (see Figure 3.9). No further effects were found. The means and standard errors can be examined in Table 3.8.

Table 3.8. Means and standard errors (SE) of fetuses ‘Arms-crossed’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	8.23	4.94	26.09	5.31		
Control	13.53	10.68	35.15	11.47	24.34	7.83
Mother	6.67	6.90	7.69	7.41	7.18	5.06
Father	4.40	8.18	23.08	8.79	13.74	6.01
Stranger	8.33	10.17	28.46	10.93	23.40	7.46

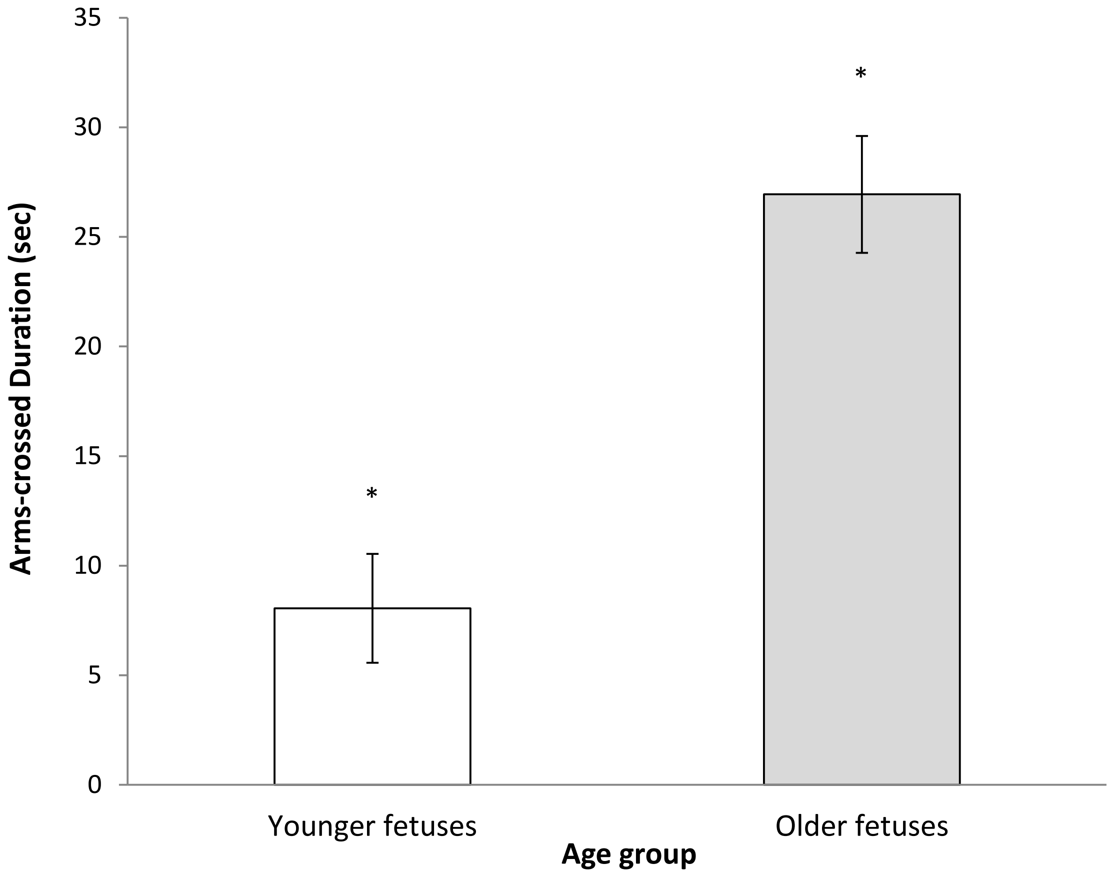

Figure 3.9. Average ‘Arms-crossed’ duration (in seconds) including standard errors for GA (younger and older fetuses) (*<.05).

Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Face press’. The main effect of Condition indicates a trend, F (3, 78) = 2.37, p = .077, η_p^2 = .08. Neither a main effect of GA F (1, 26) = 1.08, p = .308, η_p^2 = .04, nor an interaction F (3, 78) = 0.57, p = .640, η_p^2 = .02, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 6.53, p = .017, η_p^2 = .20 of Condition, indicating an increase from ‘Control’ (M = 1.23) over ‘Mother’ (M = 2.79) to ‘Father’ (M = 2.79) followed by a decrease to ‘Stranger’ (M = 1.69).

Post-hoc pairwise comparison of the Condition main effect of Condition showed a tendency (p = .077) between ‘Control’ and ‘Father’ with a higher frequency in ‘Face press’ in ‘Father’ compared to ‘Control’ with no other significant differences between conditions (see Figure 2.10). No further effects were found. The means and standard errors can be examined in Table 3.9.

Table 3.9. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.30	0.53	1.50	0.56		
Control	2.00	0.63	0.46	0.67	1.23	0.46
Mother	2.40	0.74	1.39	0.79	1.89	0.54
Father	2.80	0.80	2.77	0.79	2.79	0.59
Stranger	2.00	0.72	1.39	0.78	1.69	0.53

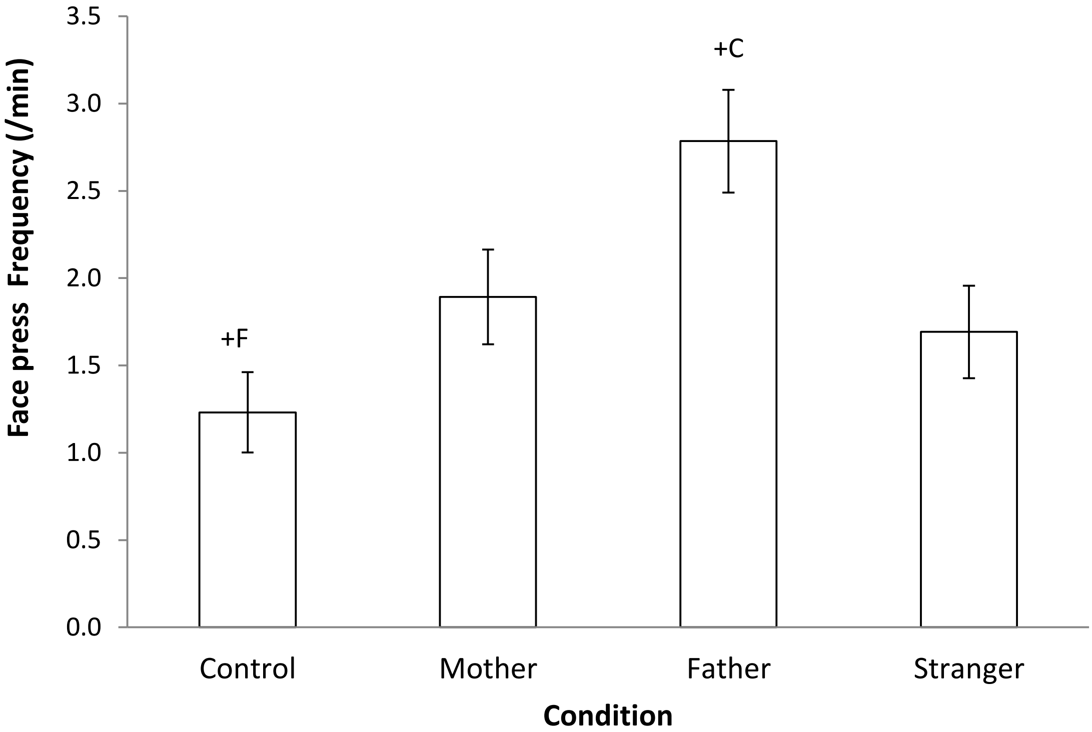

Figure 3.10. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Face press’ Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Face press’. The main effect of Condition indicates a trend, F (3, 78) = 2.37, p = .077, η_p^2 = .08. No main effects of GA F (1, 26) = 0.95, p = .339, η_p^2 = .04, or an interaction F (3, 78) = 0.53, p = .663, η_p^2 = .02, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 5.28, p = .030, η_p^2 = .17, of Condition. Overall, an increase is produced by the means from ‘Control’ (M = 20.51) to the ‘Father’ condition (M = 46.41), over ‘Mother’ (M = 29.19). However, the ‘Stranger’ condition has a somewhat lower mean (M = 28.21) producing the quadratic trend.

Post-hoc pairwise comparison of the Condition main effect showed a tendency (p = .077) between ‘Control’ and ‘Father’ with a longer duration of ‘Face press’ in ‘Father’ compared to ‘Control’ (see Figure 3.11). No other significant differences were found between conditions. No further effects were found. The means and standard errors can be examined in Table 3.10.

Table 3.10. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	37.16	8.51	25.00	9.14		
Control	33.33	10.45	7.69	11.22	20.51	7.67
Mother	35.29	11.78	23.08	12.65	29.19	8.64
Father	46.67	13.36	46.15	14.35	46.41	9.81
Stranger	33.33	12.03	23.08	12.92	28.21	8.83

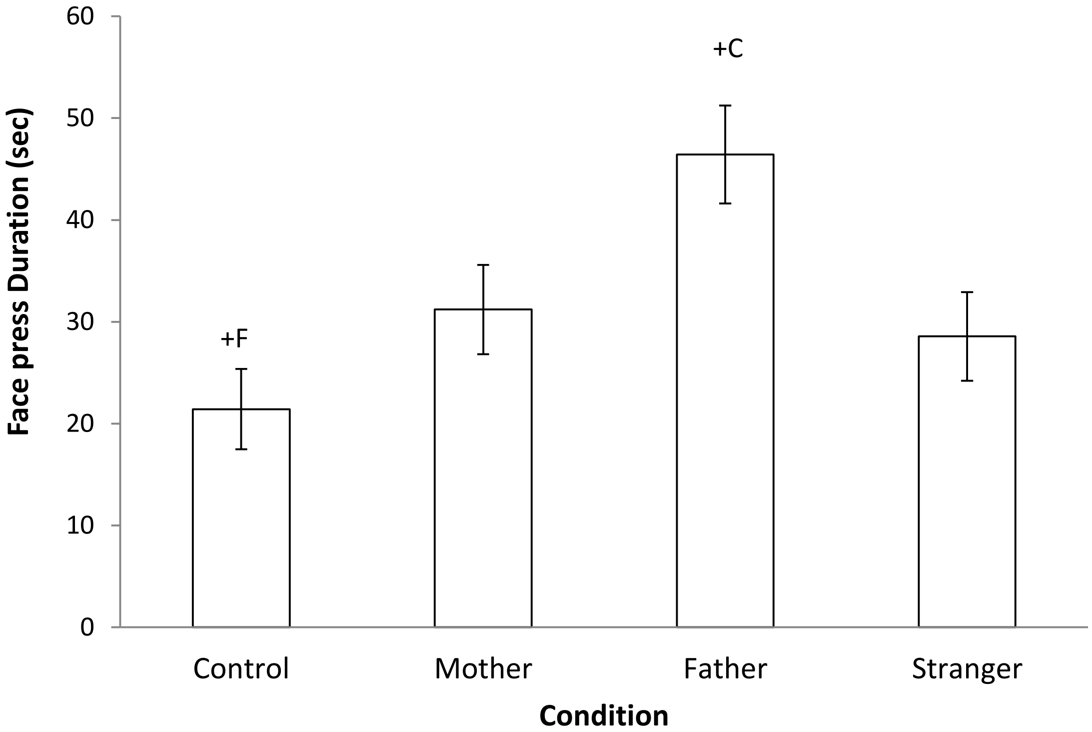

Figure 3.11. Average ‘Face press’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

0-10s Interval analysis: Combined variables

Repeated-measures ANOVA Condition: ‘Inactivity/Resting’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Inactivity/Resting’ frequency between the four Conditions (Control, Mother, Father, Stranger). Results showed a tendency for a main effect of Condition F (3, 81) = 2.39, p = .075, η_p^2 = .08. Examination of the means suggests that fetuses altered ‘Inactivity/Resting’ frequency between Conditions. Polynomial contrasts indicated, in support of this, a tendency for a quadratic trend, F (1, 27) = 4.23, p = .050, η_p^2 = .14. Overall, there is a decrease produced by the means from ‘Control’ (M = 3.00) to ‘Mother’ (M = 1.29) followed by an increase to ‘Father’ (M = 2.36) and ‘Stranger’ (M = 3.21) producing the quadratic trend.

Post-hoc pairwise comparison revealed a tendency for a difference between 'Mother' and 'Stranger' conditions, with a higher 'Inactivity/Resting' frequency during stranger's touch (M = 3.21) compared to 'Mother' (M = 1.29, *p* = .059) implying that the fetus was more active when the mother touched the abdomen compared to a stranger (see Figure 3.12). No further effects were found. The means and standard errors can be examined in Table 3.11.

Table 3.11. Means and standard errors (SE) on the frequency of fetuses 'Inactivity/Resting' across conditions.

	Control	Mother	Father	Stranger
Mean	3.00	1.29	2.36	3.21
SE	0.66	0.47	0.56	0.58

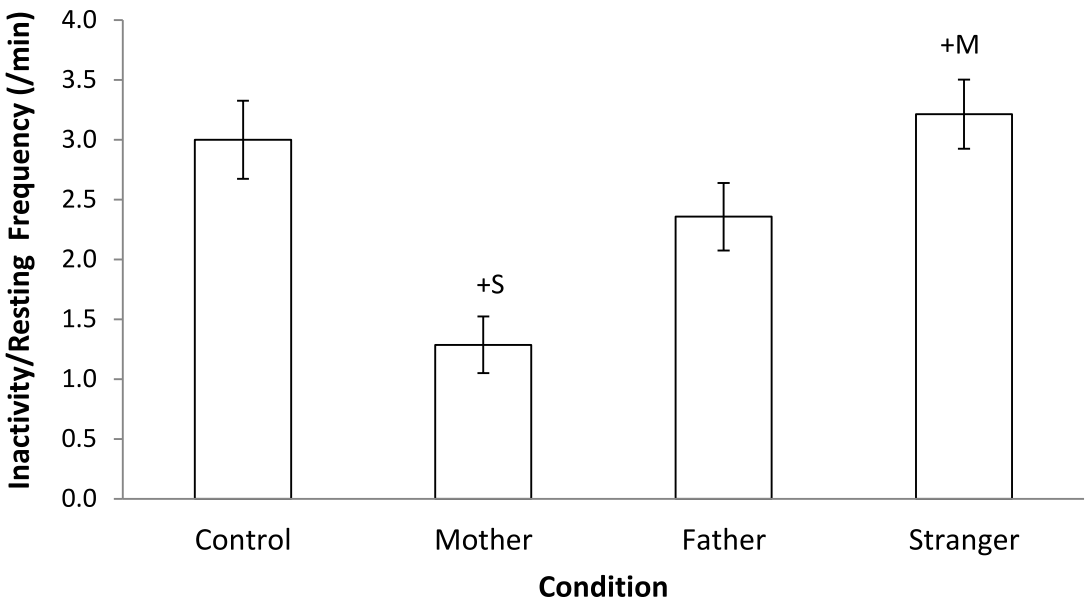

Figure 3.12. Average 'Inactivity/Resting' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'General Movement' Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'General movement'. Results showed no significant main effect of Condition F (3, 78) = 0.69, p = .561, η_p^2 = .03, or an interaction F (3, 78) = 0.66, p = .580, η_p^2 = .03. However, a tendency of the main effect of GA, F (1, 26) = 3.18, p = .086, η_p^2 = .11, was found.

Post-hoc pairwise comparison of the main effect of GA showed that younger fetuses (M = 4.42) tend to display prolonged 'General movements' compared to older fetuses (M = 2.73, p = .086) (see Figure 3.13). No further effects were found. The means and standard errors can be examined in Table 3.12.

Table 3.12. Means and standard errors (SE) of fetuses 'General movement' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	4.42	0.65	2.73	0.69		
Control	4.76	1.48	2.10	1.59	3.43	1.09
Mother	5.48	1.40	2.86	1.50	4.17	1.02
Father	5.23	1.32	3.15	1.41	4.19	0.97
Stranger	2.23	0.91	2.81	0.97	2.52	0.67

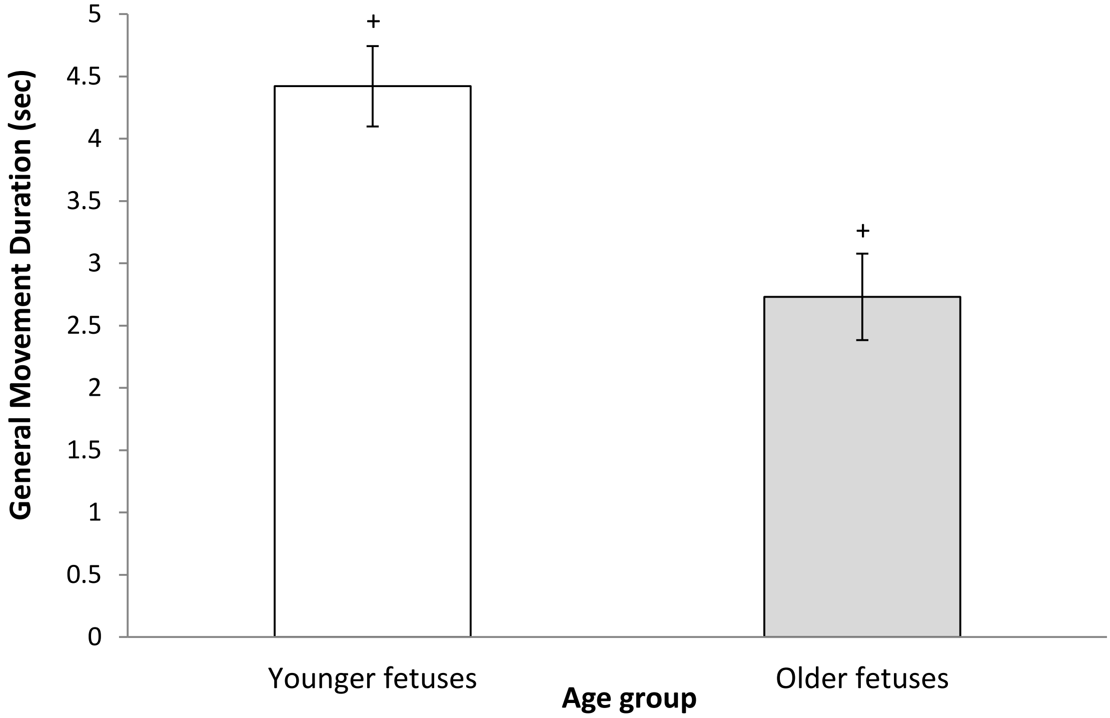

Figure 3.13. Average 'General movement' duration (in seconds) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Self-touch' Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Self-touch'. Results showed no main effect of Condition F (3, 78) = 0.96, p = .415, η_p^2 = .04, and no significant main effect of GA F (1, 26) = 0.00, p = .986, $\eta_p^2 < .001$, but a tendency for an interaction between Condition and GA, F (3, 78) = 2.19, p = .096, η_p^2 = .08, was found. In support of this polynomial contrasts of the interaction show a significant linear trend of Condition and GA F (1, 26) = 4.35, p = .047, η_p^2 = .14.

Post-hoc pairwise comparison of the interaction between Condition and GA showed a significant difference in 'Stranger' for younger and older fetuses, with younger fetuses (M = 9.60) engaging in significantly longer 'Self-touch' compared to older fetuses (M = 6.51, p = .025) (see Figure 3.14). No further effects were found. The means and standard errors can be examined in Table 3.13.

Table 3.13. Means and standard errors (SE) of fetuses 'Self-touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.74	0.44	7.75	0.47		
Control	7.60	0.82	9.40	0.88	8.50	0.60
Mother	6.85	1.18	6.65	1.26	6.75	0.86
Father	6.92	1.07	8.46	1.15	7.69	0.78
Stranger	9.60	0.88	6.51	0.95	8.05	0.65

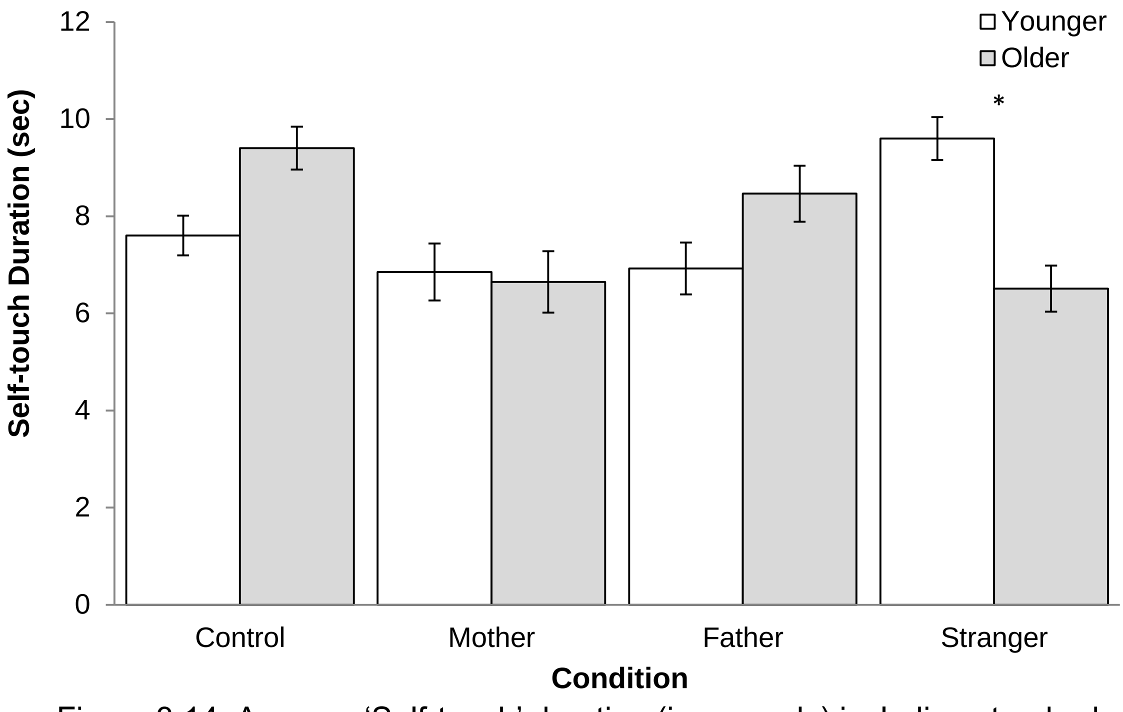

Figure 3.14. Average 'Self-touch' duration (in seconds) including standard errors for each condition (*< .05).

Mixed-design ANOVA Condition*GA: 'Inactivity/Resting' Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Inactivity/Resting'. The main effect of Condition indicates a trend, F (3, 78) =

2.69, p = .052, η_p^2 = .09. Neither a main effect of GA F (1, 26) = 1.74, p = .199 η_p^2 = .06, nor an interaction F (3, 78) = 1.54, p = .210, η_p^2 = .06, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 5.27, p = .030, η_p^2 = .17 of Condition, indicating a decrease from 'Control' (M = 3.08) to 'Mother' (M = 1.26), followed by an increase to 'Father' (M = 2.35) and 'Stranger' (M = 3.28).

Post-hoc pairwise comparison of the Condition main effect showed a significant difference between 'Mother' and 'Stranger' with a higher frequency of 'Inactivity/Resting' in 'Stanger' (M = 5.03) compared to 'Mother' (M = 1.95, p = .034) (see Figure 3.15). No further effects were found. The means and standard errors can be examined in Table 3.14.

Table 3.14. Means and standard errors (SE) of fetuses 'Inactivity/Resting' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.83	0.58	4.53	0.62		
Control	2.69	1.22	5.82	1.31	4.25	0.90
Mother	2.37	1.03	1.54	1.11	1.95	0.76
Father	3.11	1.24	3.85	1.33	3.48	0.91
Stranger	3.15	1.20	6.92	1.28	5.03	0.88

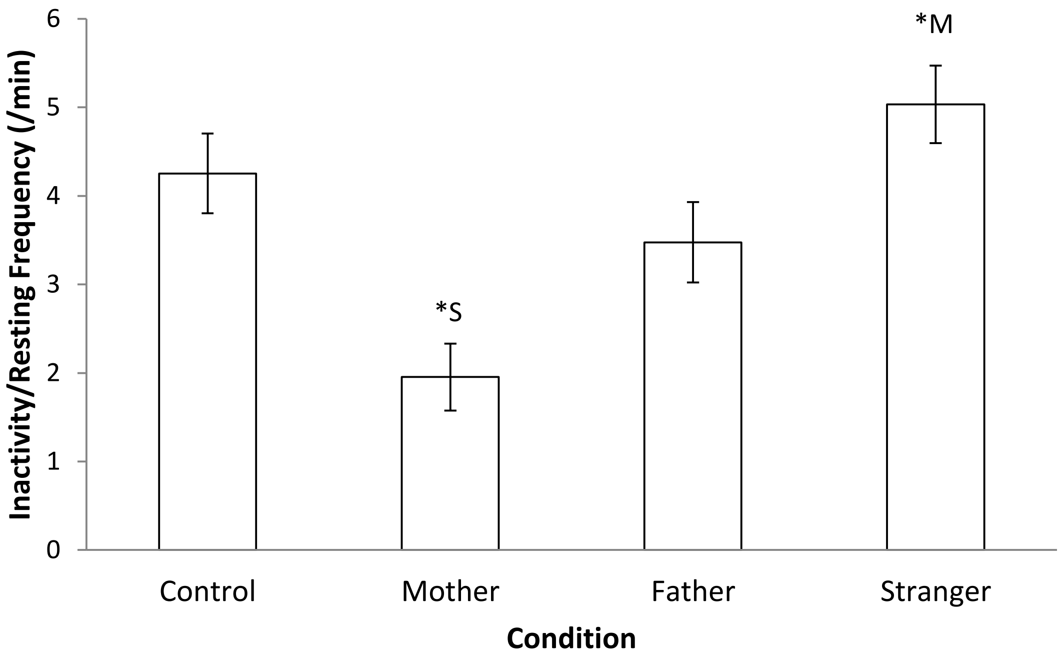

Figure 3.15. Average ‘Inactivity/Resting’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Inactivity/Resting’ Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Inactivity/Resting’. The main effect of Condition indicates a trend, F (3, 78) = 2.31, p = .083, η_p^2 = .08. A further tendency of main effect of GA F (1, 26) = 4.02, p = .055, η_p^2 = .13, was found (see Figure x). No significant interaction F (3, 78) = 1.53, p = .215, η_p^2 = .06, was found. In support of this polynomial contrasts indicated a tendency for a quadratic trend F (1, 26) = 3.70, p = .066, η_p^2 = .12, of Condition, indicating a decrease from ‘Control’ (M = 4.25) to ‘Mother’ (M = 1.95), followed by an increase to ‘Father’ (M = 3.47) and ‘Stranger’ (M = 5.03).

Post-hoc pairwise comparison of the Condition main effect showed a tendency between ‘Mother’ and ‘Stranger’ with a higher duration of ‘Inactivity/Resting’ in ‘Stranger’ (M = 3.28) compared to ‘Mother’ (M = 1.26, p = .092) (see Figure 3.16). Post-hoc pairwise comparison of the main effect of GA showed that older fetuses (M = 2.89) displayed more ‘Inactivity/resting’ than younger fetuses (M = 2.10, *p*= .055) (see Figure 3.17). No further effects were found. The means and standard errors can be examined in Table 3.15.

Table 3.15. Means and standard errors (SE) of fetuses 'Inactivity/Resting' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.10	0.41	2.89	0.44		
Control	2.00	0.87	4.15	0.93	3.08	0.64
Mother	1.60	0.65	0.92	0.70	1.26	0.48
Father	2.40	0.79	2.31	0.84	2.35	0.58
Stranger	2.40	0.77	4.15	0.82	3.28	0.56

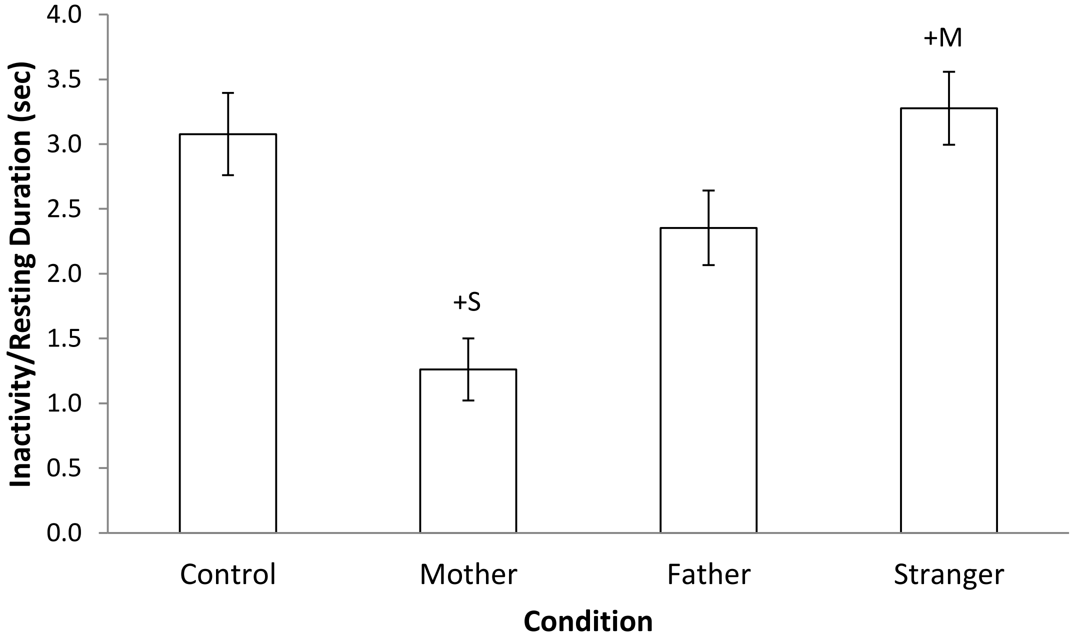

Figure 3.16. Average 'Inactivity/Resting' duration (in seconds) including standard errors for each condition (*< .05).

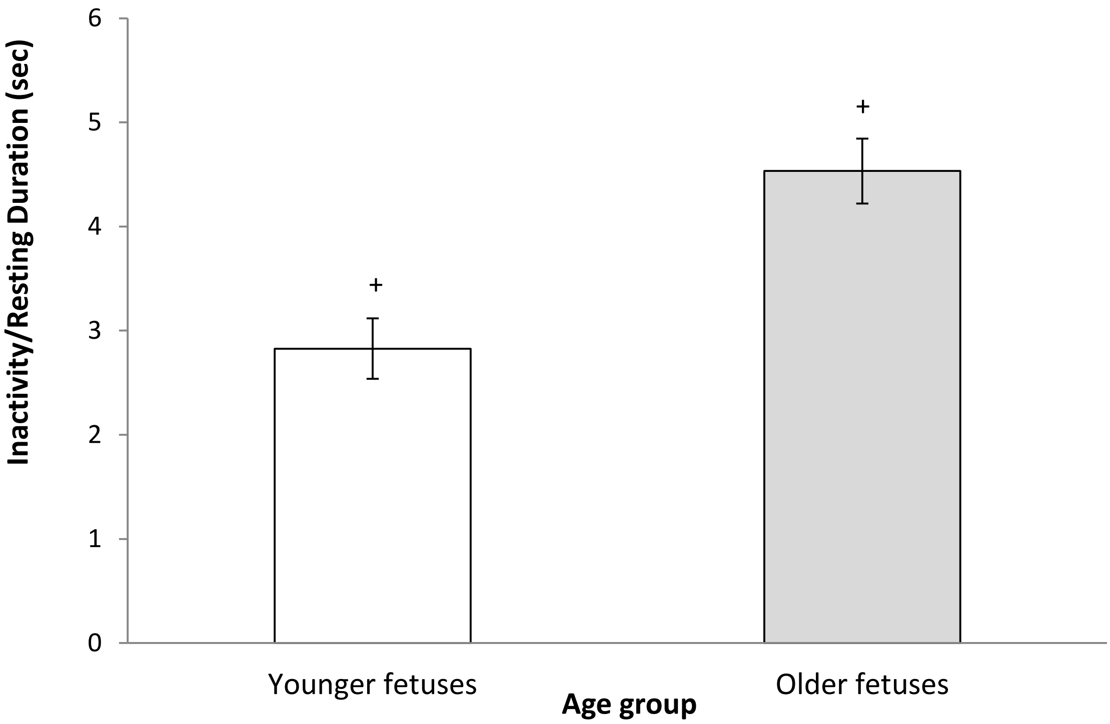

Figure 3.17. Average ‘Inactivity/Resting’ duration (in seconds) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

0-15 Interval analysis

Repeated-measures ANOVA Condition: ‘Arm Movement’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Arm movement’ frequency between the four conditions (Control, Mother, Father, Stranger). Results showed a tendency for a main effect of Condition F (3, 81) = 2.27, p = .086, η_p^2 = .08. Examination of the means suggests that fetuses altered ‘Arm movement’ frequency between Conditions. In support of this polynomial contrasts indicated a significant quadratic trend, F (1, 27) = 6.08, p = .020, η_p^2 = .18. Overall, there is an increase produced by the means from ‘Control’ (M = 3.43) to the ‘Mother’ (M = 6.86) followed by a decrease to ‘Father’ (M = 6.57) and ‘Stranger’ (M = 4.86) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.18). The means and standard errors can be examined in Table 3.16.

Table 3.16. Means and standard errors (SE) on the frequency of fetuses ‘Arm movements’ across conditions.

	Control	Mother	Father	Stranger
Mean	3.43	6.86	6.57	4.86
SE	0.91	1.20	1.22	1.02

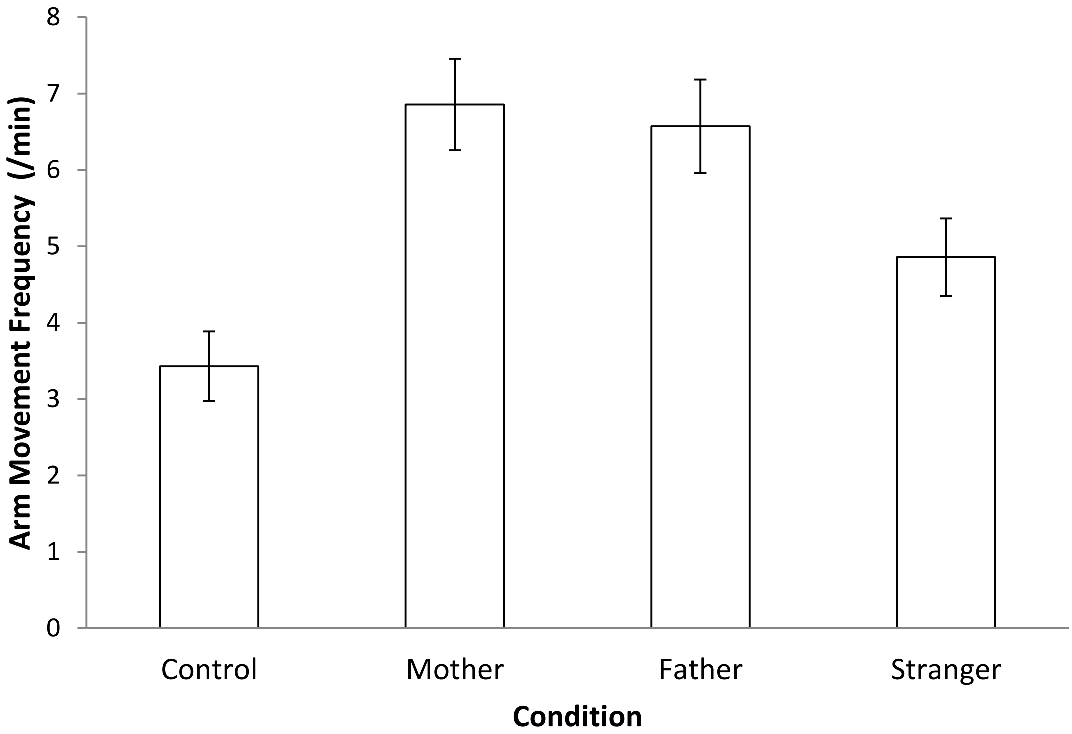

Figure 3.18. Average ‘Arm movement’ frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: ‘Face press’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the ‘Face press’ between the four Conditions (Control, Mother, Father, Stranger). Results showed a tendency towards a main effect of Condition F (3, 81) = 2.19, p = .096, η_p^2 = .08. Examination of means suggests that fetuses ‘Face press’ frequency differed between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant quadratic trend, F (1, 27) = 7.73, p = .010, η_p^2 = .22. Overall, there is an increase produced by the means from ‘Control’ (M = 0.86) over ‘Mother’ (M = 1.43) to ‘Father’ (M = 1.86). However, the ‘Stranger’ condition has a somewhat lower mean (M = 1.14) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.19). The means and standard errors can be examined in Table 3.17.

Table 3.17. Means and standard errors (SE) on the frequency of fetuses ‘Face press’ against the uterus across conditions.

	Control	Mother	Father	Stranger
Mean	0.86	1.43	1.86	1.14
SE	0.32	0.42	0.38	0.35

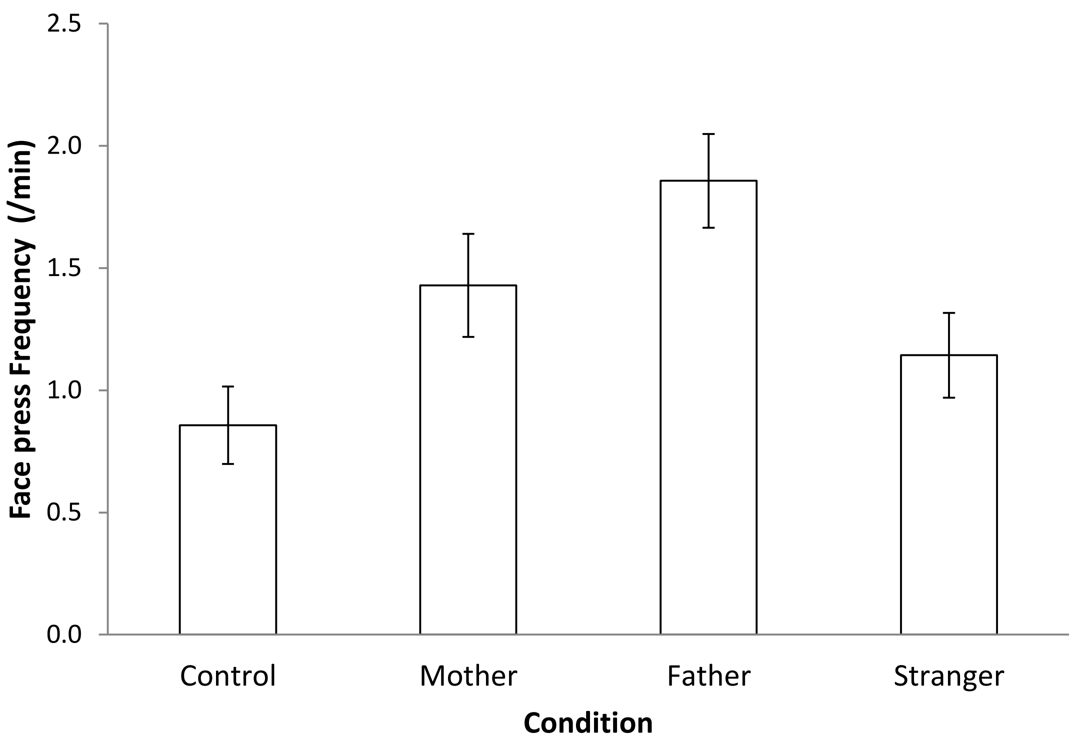

Figure 3.19. Average ‘Face press’ frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in duration of the ‘Face press’ between the four Conditions (Control, Mother, Father, Stranger). Results indicate that there was a tendency for a difference in ‘Face press’ duration between the four Conditions F (3, 81) = 2.27, p = .086, η_p^2 = .08. Examination of these means suggests that ‘Face press’ duration differentiated between conditions. Polynomial contrasts indicated, in support of this, that there was a significant quadratic trend, F (1, 27) = 5.43, p = .027, η_p^2 = .17. Overall, there is an increase produced by the means from ‘Control’ (M = 21.43) over ‘Mother’ (M = 30.42) to ‘Father’ (M = 46.43). However, the ‘Stranger’ condition has a somewhat lower mean (M = 28.57) than producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.20). The means and standard errors can be examined in Table 3.18.

Table 3.18. Means and standard errors (SE) on the duration of fetuses ’Face press’ of the uterus across conditions.

	Control	Mother	Father	Stranger
Mean	21.43	30.42	46.43	28.57
SE	7.90	8.63	9.60	8.69

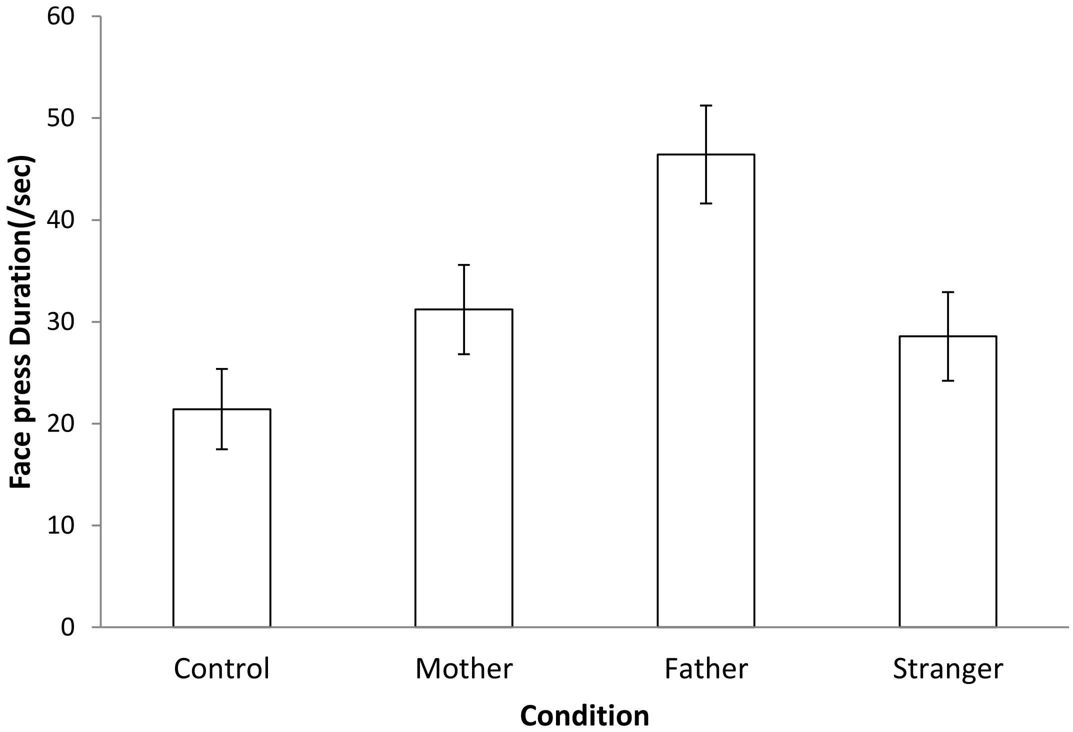

Figure 3.20. Average 'Face press' duration (in seconds) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: 'Arm Movement' Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Arm movement'. The main effect of Condition indicates a trend, F (3, 78) = 2.25, p = .089, η_p^2 = .08. No significant main effect of GA F (1, 26) = 0.83, p = .371, η_p^2 = .03, or an interaction F (3, 78) = 0.55, p = .65, η_p^2 = .02, were found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 26) = 5.95, p = .022, η_p^2 = .19. Overall, there is an increase produced by the means from 'Control' (M = 3.41) over 'Mother' (M = 6.89) to 'Father' (M = 6.48). However, the 'Stranger' condition has a somewhat lower mean (M = 4.78) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.21). The means and standard errors can be examined in Table 3.19.

Table 3.19. Means and standard errors (SE) of fetuses 'Arm movement' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	5.93	0.81	4.85	0.88		
Control	3.73	1.27	3.08	1.36	3.41	0.93
Mother	6.40	1.66	7.39	1.79	6.89	1.22
Father	7.73	1.66	5.23	1.79	6.48	1.22
Stranger	5.87	1.38	3.69	1.49	4.78	1.02

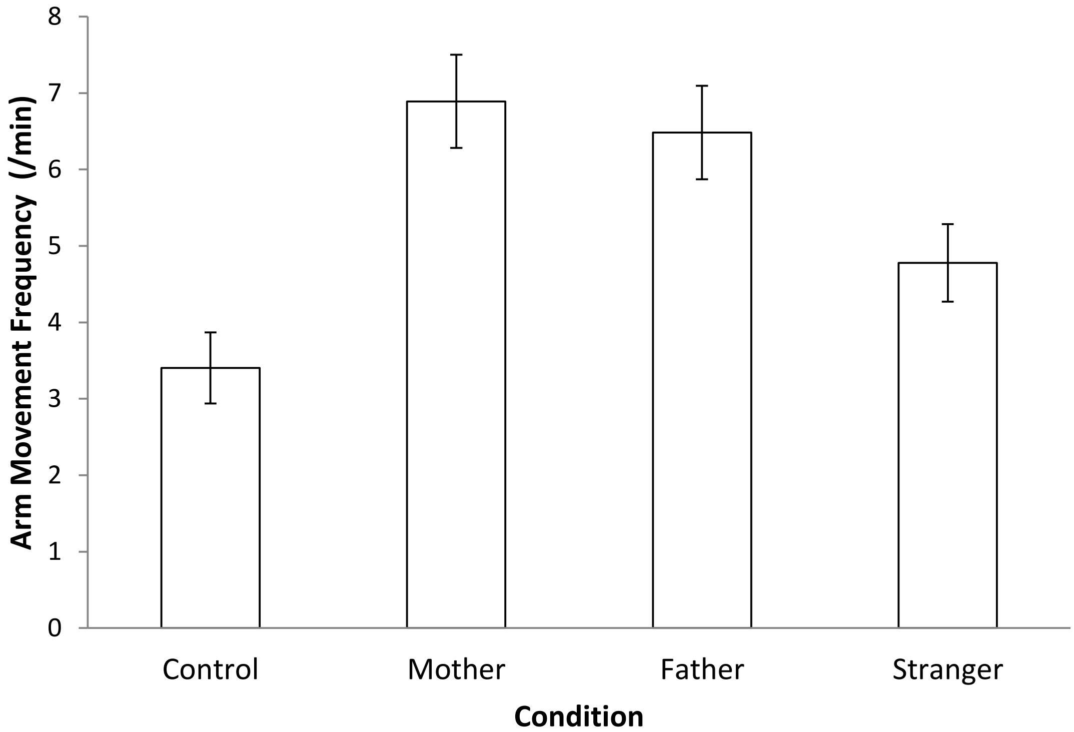

Figure 3.21. Average 'Arm movement' frequency (per minute) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: 'Body Touch' Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Body touch'. Results showed no interaction between Condition and GA, F (3, 78) = 0.7, p = .792, $\eta_p^2 < .001$, no main effect of Condition F (3, 78) = 0.51, p = .679, $\eta_p^2 = .02$, and no significant main effect of GA F (1, 26) = 0.07, p = .798, $\eta_p^2 < .001$. In support of this polynomial contrasts of the interaction showed a significant quadratic trend of Condition and GA F (1, 26) = 5.09, p = .033, $\eta_p^2 = .16$.

Post-hoc pairwise comparison of the interaction between Condition and GA showed a significant difference in 'Control' for younger and older fetuses, with older fetuses (M = 3.39) touching the body more compared to younger fetuses (M = 0.80, p = .040). Older fetuses decreased touch during fathers touch (M = 0.62) compared to 'Control' (M = 3.39, p = 0.93) (see Figures 3.22 and 3.23). No further effects were found. The means and standard errors can be examined in Table 3.20.

Table 3.20. Means and standard errors (SE) of fetuses 'Body touch' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	5.93	0.81	4.85	0.88		
Control	0.80	0.81	3.39	0.87	2.09	0.60
Mother	1.87	0.69	0.62	0.74	1.24	0.50
Father	2.13	0.74	0.62	0.80	1.37	0.55
Stranger	1.60	0.65	1.23	0.70	1.42	0.48

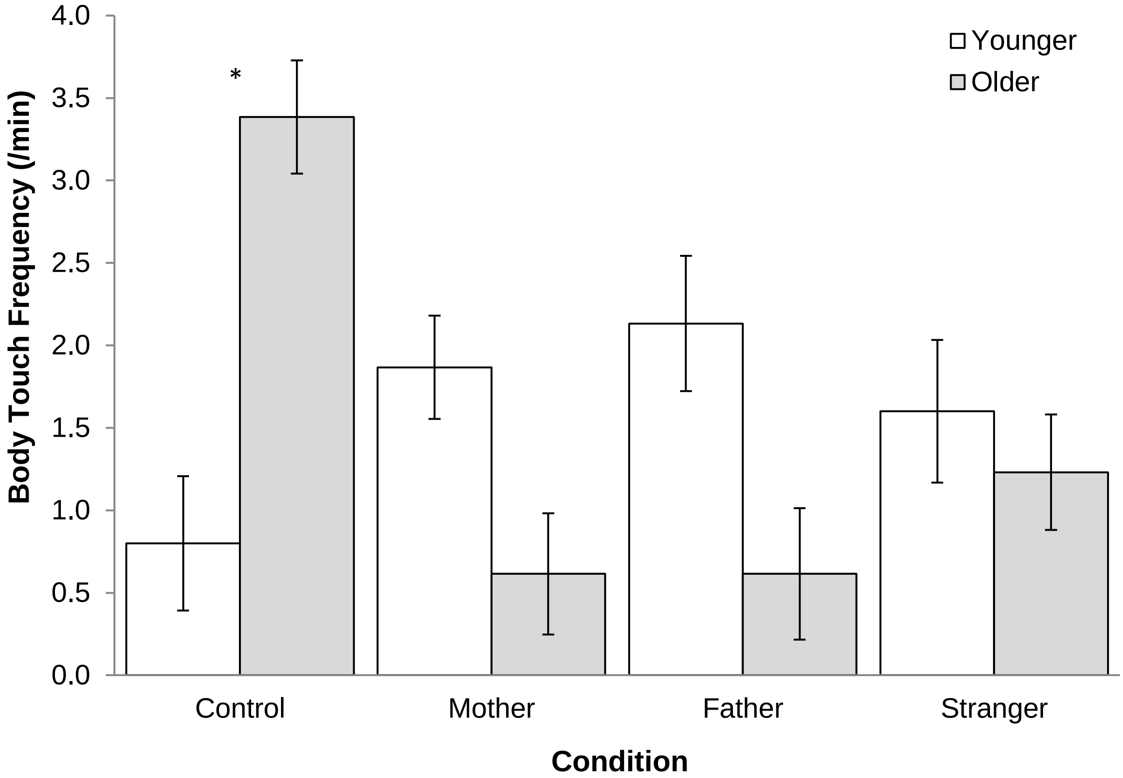

Figure 3.22. Average ‘Body touch’ frequency (per minute) including standard errors for each condition (*< .05).

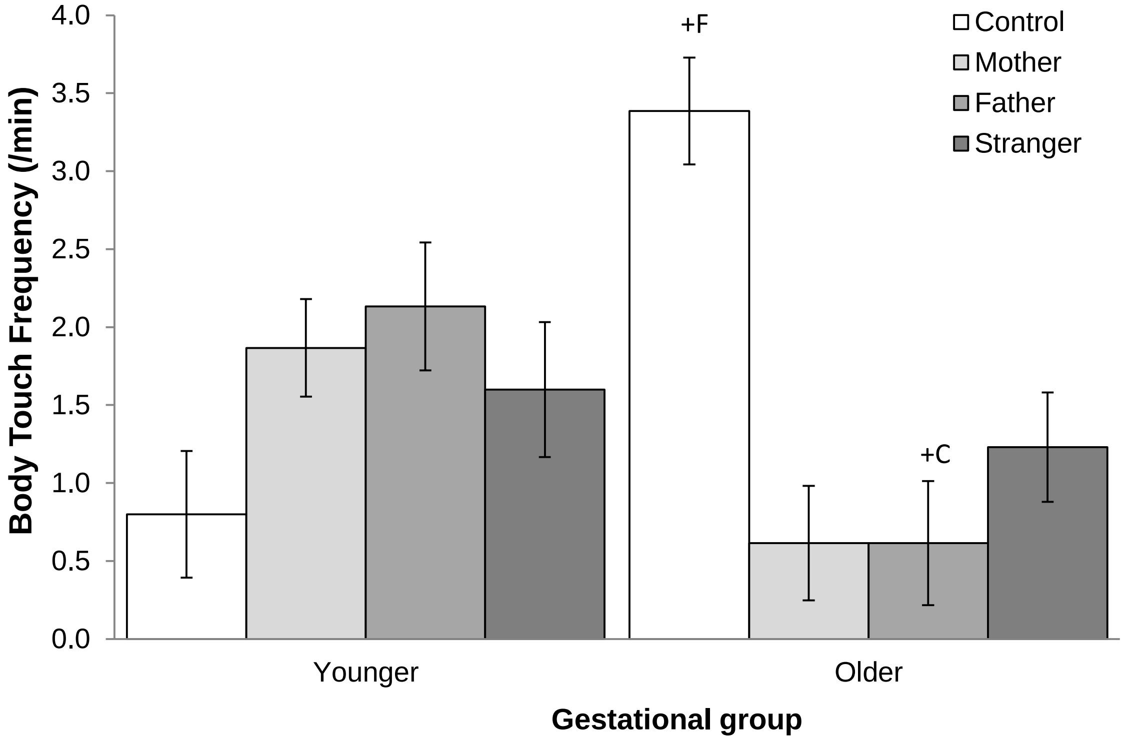

Figure 3.23. Average ‘Body touch’ frequency (in minutes) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Uterus touch’. Results indicated a tendency for an interaction between Condition and GA, F (3, 78) = 2.19, p = .096, η_p^2 = .08. No main effect of Condition F (3, 78) = 0.27, p = .844, η_p^2 = .01, or GA F (1, 26) = 0.03, p = .864, η_p^2 < .001, was found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 5.71, p = .024, η_p^2 = .18 of Condition and GA.

Post-hoc pairwise comparison of the interaction between Condition and GA showed that younger fetuses (M = 2.13) touch the uterus significantly more during fathers’ touch compared to older fetuses (M = 0.62, p = .038) (see Figure 3.24). No further effects were found. The means and standard errors can be examined in Table 3.21.

Table 3.21. Means and standard errors (SE) of fetuses ‘Uterus touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.47	0.32	1.39	0.35		
Control	1.60	0.57	0.92	0.61	1.26	0.42
Mother	1.33	0.77	2.15	0.83	1.74	0.57
Father	2.13	0.47	0.62	0.51	1.37	0.35
Stranger	0.80	0.48	1.85	0.52	1.32	0.35

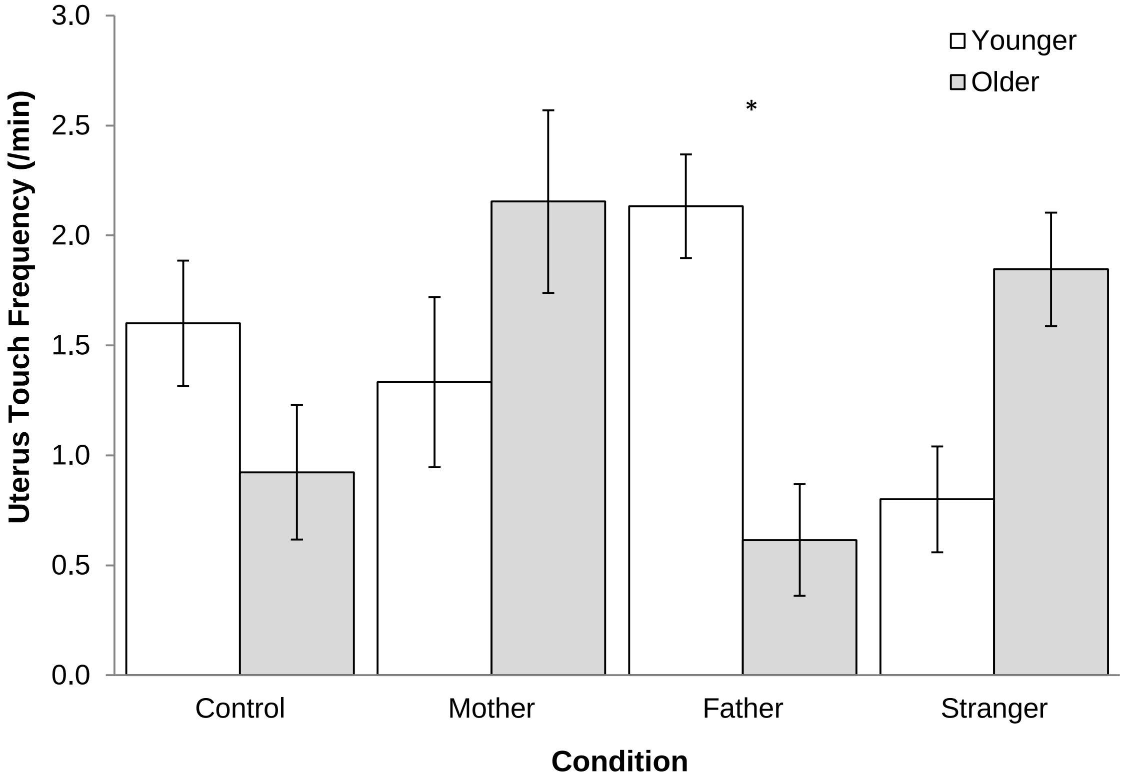

Figure 3.24. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions across gestational ages (younger and older fetuses) (*<.05).

Mixed-design ANOVA Condition*GA: ‘Arms-crossed’ Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Arms-crossed’. Results indicate a significant main effect of GA, F (1, 26) = 6.70, p = .016, η_p^2 = .21. No main effect of Condition F (3, 78) = 1.48 p = .227, η_p^2 = .05, or an interaction F (3, 78) = 0.98, p = .406, η_p^2 = .04, was found.

Post-hoc pairwise comparison of the main effect of GA showed a significant difference with older fetuses (M = 26.94) displaying longer ‘Arms-crossed’ compared to younger fetuses (M = 8.06, p = .016) (see Figure 3.25). No further effects were found. The means and standard errors can be examined in Table 3.22.

Table 3.22. Means and standard errors (SE) of fetuses 'Arms-crossed' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	8.06	4.97	26.94	5.34		
Control	13.47	10.62	33.69	11.41	23.58	7.79
Mother	7.50	6.96	9.97	7.48	8.73	5.12
Father	3.47	8.01	23.08	8.61	13.27	5.88
Stranger	7.81	9.95	41.03	10.69	24.42	7.30

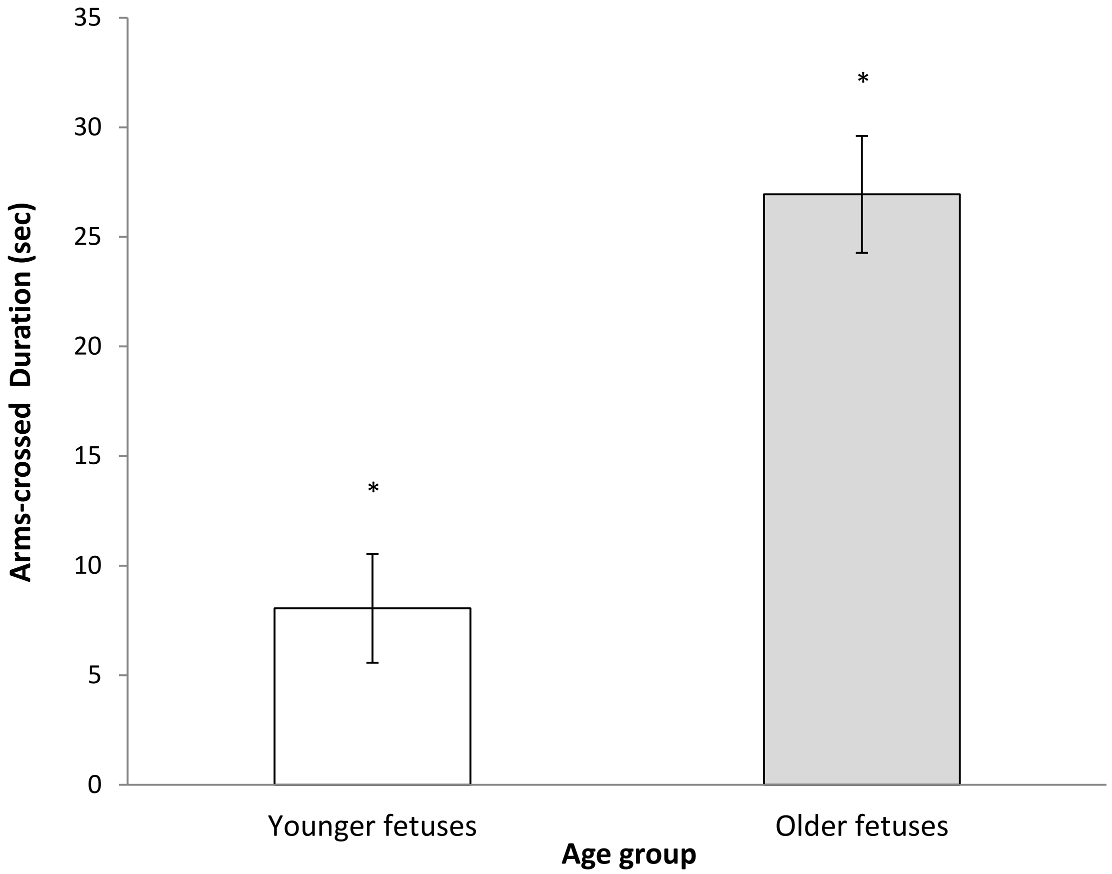

Figure 3.25. Average 'Arms-crossed' duration (in seconds) including standard errors for GA (younger and older fetuses) (*< .05).

Mixed-design ANOVA Condition*GA: 'Face press' Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Face press'. The Condition main effect indicates a trend, F (3, 78) = 2.28, p = .086, η_p^2 = .08. Neither main effects of GA F (1, 26) = 1.08, p = .308, η_p^2 = .04, nor an interaction F (3, 78) = 0.58, p = .579, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 7.67, p = .010, η_p^2 = .23, of Condition, indicating an increase from 'Control' (M = 0.82) over 'Mother' (M = 1.40) to 'Father' (M = 1.86) followed by a decrease to 'Stranger' (M = 1.13).

Post-hoc pairwise comparison of the Condition main effect showed a tendency (p = .077) between 'Control' and 'Father' with a higher frequency in 'Face press' in 'Father' (M = 1.86) compared to 'Control' (M = 0.82) (see Figure 3.26). No further effects were found. The means and standard errors can be examined in Table 3.23.

Table 3.23. Means and standard errors (SE) of fetuses 'Face press' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.60	0.37	1.00	0.40		
Control	1.33	0.42	0.31	0.45	0.82	0.31
Mother	1.87	0.57	0.92	0.62	1.40	0.42
Father	1.87	0.54	1.85	0.57	1.86	0.39
Stranger	1.33	0.48	0.92	0.52	1.13	0.35

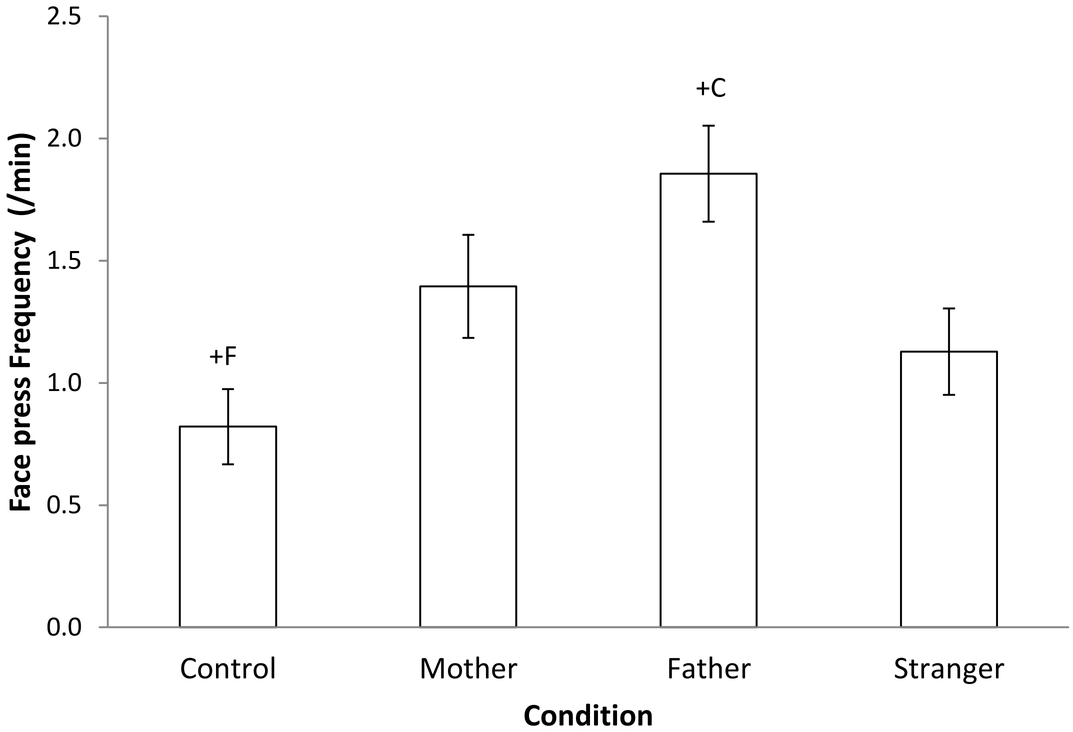

Figure 3.26. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Face press’ Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Face press’. The main effect of Condition indicates a trend, F (3, 78) = 2.37, p = .077, η_p^2 = .08. No main effect of GA F (1, 26) = 0.99, p = .329, η_p^2 = .04, or an interaction F (3, 78) = 0.54, p = .658, η_p^2 = .02, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 5.70, p = .025, η_p^2 = .18, of Condition. Overall, an increase is produced by the means from ‘Control’ (M = 20.51), over ‘Mother’ (M = 29.93), to the ‘Father’ condition (M = 46.41). However, the ‘Stranger’ condition has a somewhat lower mean (M = 28.21) producing the quadratic trend.

Post-hoc pairwise comparison of the Condition main effect showed a tendency between ‘Control’ and ‘Father’ with a longer duration of ‘Face press’ in ‘Father’ (M = 46.41) compared to ‘Control’ (M = 20.51, p = .077) (see Figure

3.27). No further effects were found. The means and standard errors can be examined in Table 3.24.

Table 3.24. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	37.53	8.57	25.00	9.21		
Control	33.33	10.45	7.69	11.22	20.51	7.67
Mother	36.79	11.87	23.08	12.75	29.93	8.71
Father	46.67	13.36	46.15	14.35	46.41	9.81
Stranger	33.33	12.03	23.08	12.92	28.21	8.83

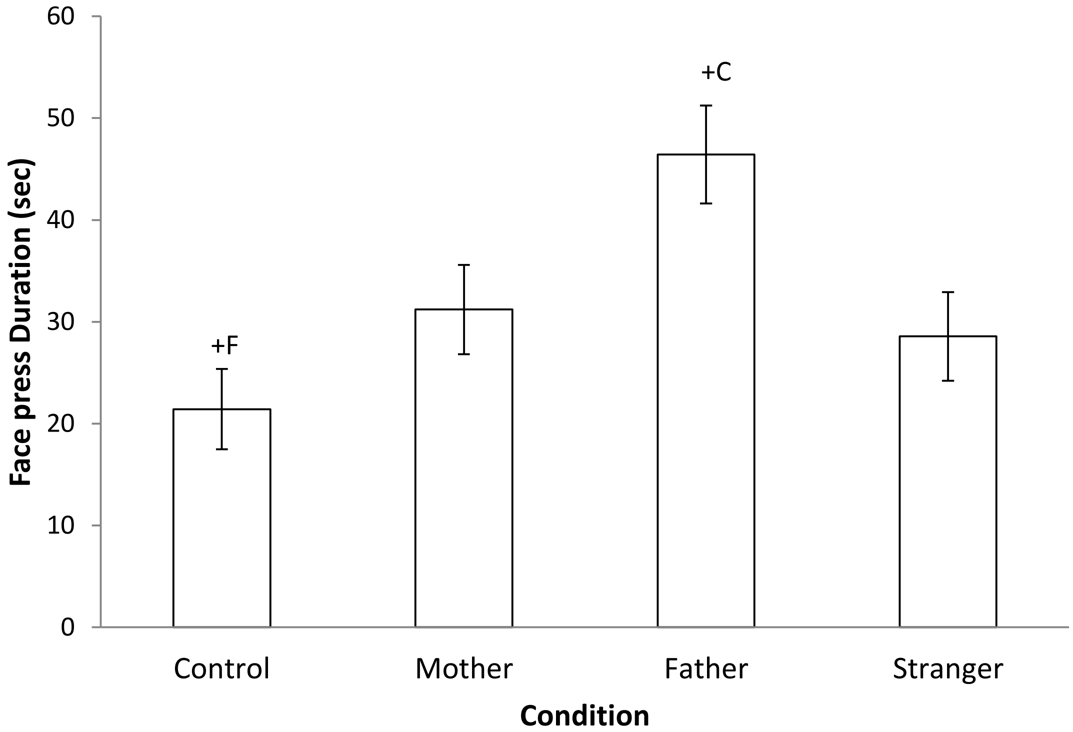

Figure 3.27. Average ‘Face press’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

0-15s Interval analysis combined

Mixed-design ANOVA Condition*GA: ‘Self-touch’ Duration

A mixed ANOVA was conducted to assess differences in ‘Self-touch’ duration and GA across the four Conditions (Control, Mother, Father, Stranger). Results showed no main effect of Condition F (3, 78) = 0.68, p = .564, η_p^2 = .03. A tendency was revealed for GA F (1, 26) = 3.28, p = .082, η_p^2 = .12, and a tendency for an interaction between Condition and GA, F (3, 78) = 2.35, p = .079, η_p^2 = .09, was found. In support of this polynomial contrasts of the interaction show a tendency for a cubic trend of Condition and GA F (1, 26) = 4.24, p = .050, η_p^2 = .15.

Post-hoc pairwise comparison of the main effect of GA revealed that older fetuses had a tendency to engage in longer ‘Self-touch’ (M = 8.15) compared to younger fetuses (M = 7.01, p = .082) (see Figure 3.30).

Post-hoc pairwise analysis of the interaction between Condition and GA showed a significant difference in ‘Mother’ for younger and older fetuses, with older fetuses (M = 8.53) engaging in significantly longer ‘Self-touch’ compared to younger fetuses (M = 5.02, p = .037). A tendency was observed for ‘Stranger’ with older fetuses engaging in more ‘Self-touch’ (M = 9.40) compared to younger fetuses (M = 6.81 p = .072) (see Figures 3.28 and 3.29).

A significant difference was observed for younger fetuses between ‘Control’ and ‘Mother’ with longer ‘Self-touch’ in ‘Control’ (M = 8.98) compared to ‘Mother’ (M = 5.02, p = .038) (see Figure x). No further effects were found. The means and standard errors can be examined in Table 3.25.

Table 3.25. Means and standard errors (SE) of fetuses ‘Self-touch’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.01	0.42	8.15	0.47		
Control	8.98	0.86	7.20	0.96	8.09	0.64
Mother	5.02	1.06	8.53	1.19	6.78	0.80
Father	7.22	1.10	7.49	1.23	7.35	0.83
Stranger	6.81	0.92	9.40	1.03	8.10	0.69

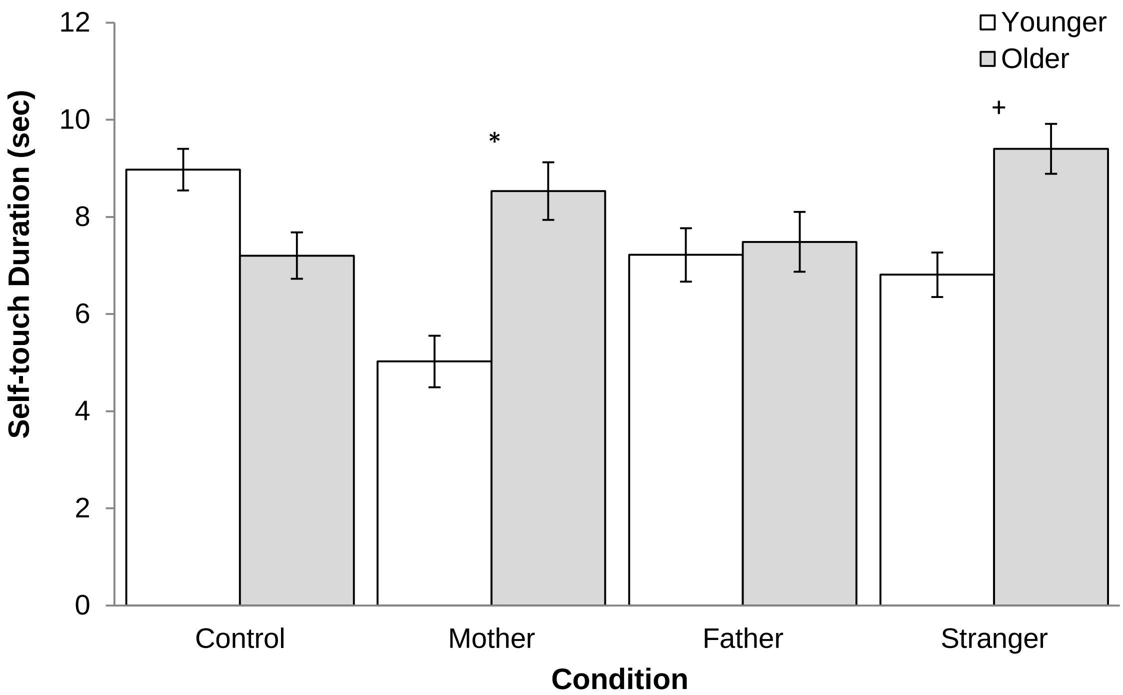

Figure 3.28. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Figure 3.29. Average ‘Self-touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

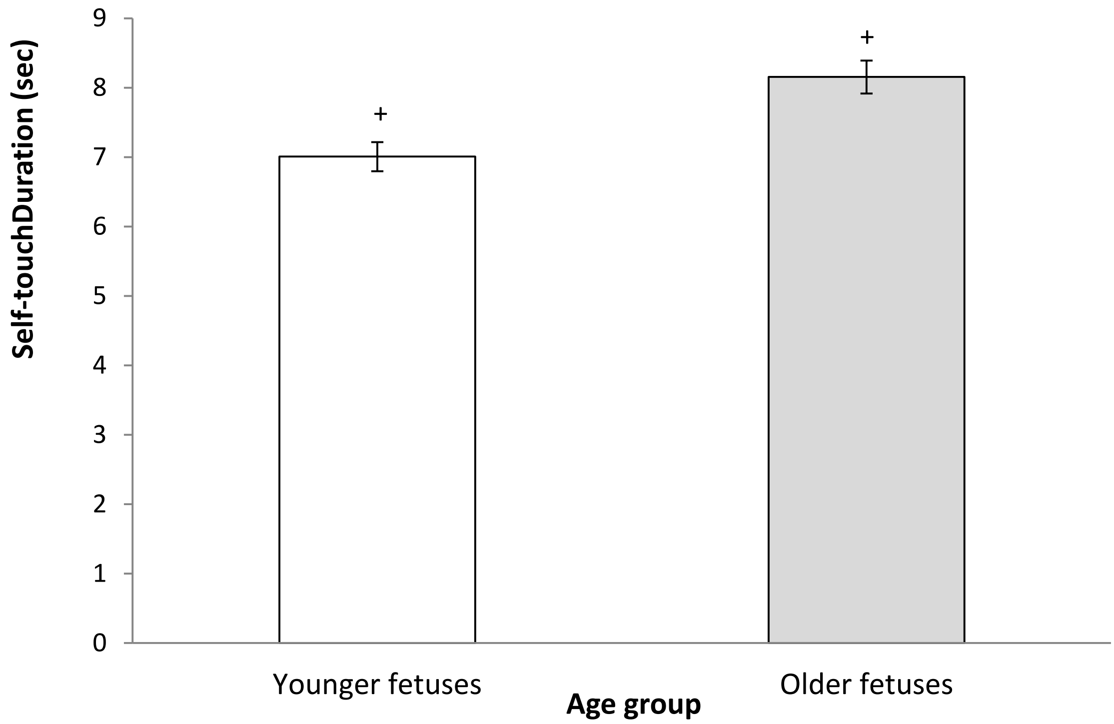

Figure 3.30. Average ‘Self-touch’ duration (in seconds) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

0-30s Interval

Repeated-measures ANOVA Condition: ‘Face press’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in frequency of the ‘Face press’ between the four Conditions (Control, Mother, Father, Stranger). Results showed a tendency between Conditions F (3, 81) = 2.19, p = .096, η_p^2 = .08. Examination of means suggests that fetuses’ ‘Face press’ frequency differed between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant quadratic trend, F (1, 27) = 7.73, p = .010, η_p^2 = .22. Overall, there is an increase produced by the means from ‘Control’ (M = 0.43), over ‘Mother’ (M = .071), to ‘Father’ (M = 0.93). However, the ‘Stranger’ condition has a somewhat lower mean (M = 0.57) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.31). The means and standard errors can be examined in Table 3.26.

Table 3.26. Means and standard errors (SE) on the frequency of fetuses 'Face press' against the uterus across conditions.

	Control	Mother	Father	Stranger
Mean	0.43	0.71	0.93	0.57
SE	0.16	0.21	0.19	0.17

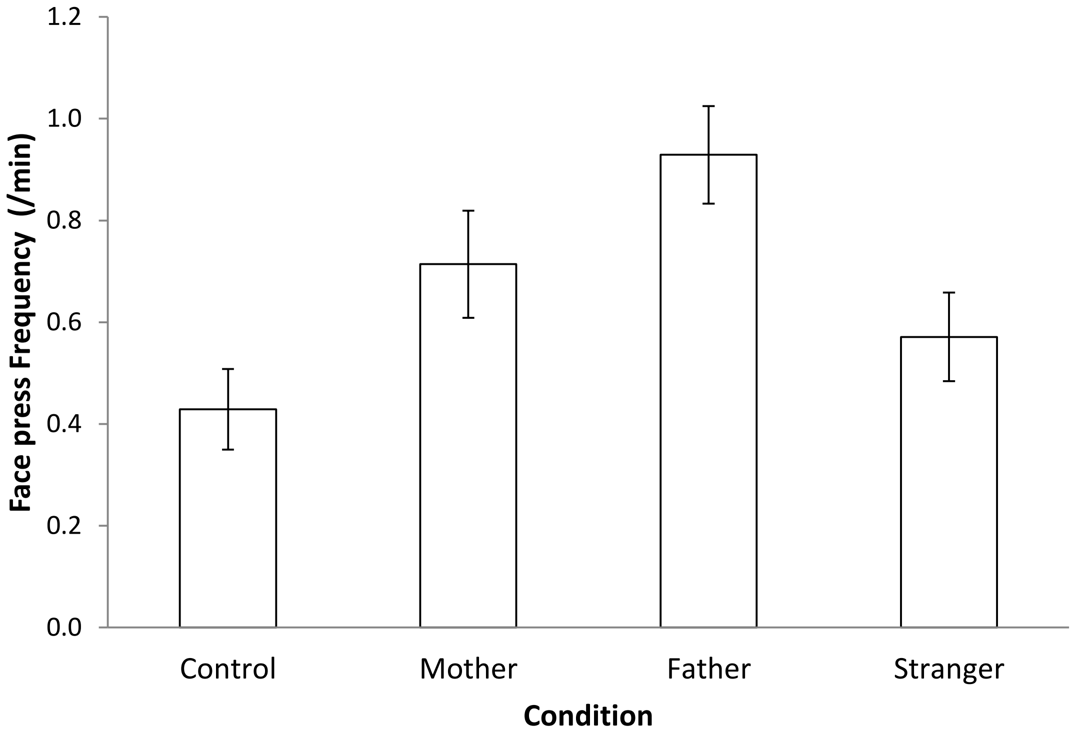

Figure 3.31. Average 'Face press' frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: 'Face press' Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in duration of the 'Face press' between the four Conditions (Control, Mother, Father, Stranger). Results indicate that there was a tendency for a main effect in 'Face press' duration between the four Conditions *F* (3, 81)

= 2.27, p = .087, η_p^2 = .08. Examination of these means suggests that 'Face press' duration differentiated between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant quadratic trend, F (1, 27) = 5.86, p = .022, η_p^2 = .18. Overall, there was an increase produced by the means from 'Control' (M = 21.43) over 'Mother' (M = 31.21) to 'Father' (M = 46.43). However, the 'Stranger' condition has a somewhat lower mean (M = 28.57) than producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.32). The means and standard errors can be examined in Table 3.27.

Table 3.27. Means and standard errors (SE) on the duration of fetuses 'Face press' against the uterus across conditions.

	Control	Mother	Father	Stranger
Mean	21.43	31.21	46.43	28.57
SE	7.90	8.76	9.60	8.69

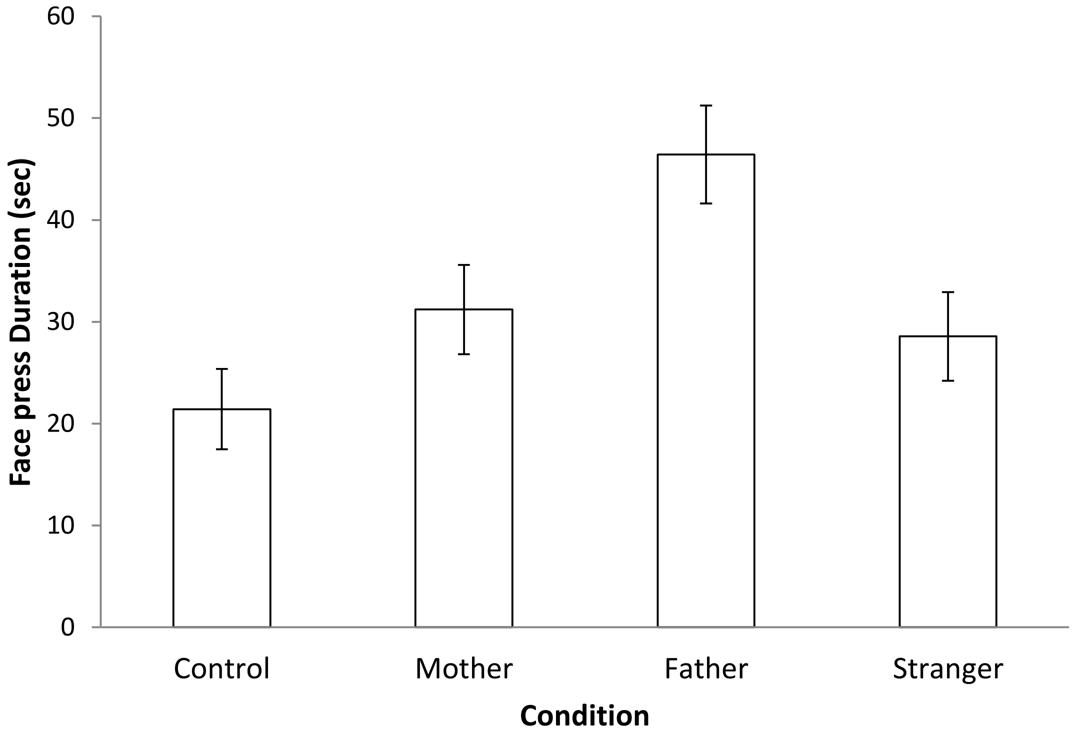

Figure 3.32. Average ‘Face press’ duration (in seconds) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: ‘Body touch’ Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Body touch’. Results showed a significant interaction between Condition and GA, F (3, 78) = 2.83, p = .044, η_p^2 = .10, but no main effect of Condition F (3, 78) = 0.78, p = .508, η_p^2 = .03, and no significant main effect of GA F (1, 26) = 0.12, p = .733, η_p^2 = .01. In support of this polynomial contrasts of the interaction showed a significant quadratic trend of Condition and GA F (1, 26) = 5.84, p = .023, η_p^2 = .18.

Post-hoc pairwise comparison of the interaction showed a tendency in ‘Control’ condition, with older fetuses (M = 2.31) touching the body more compared to younger fetuses (M = 0.80, p = .072) (see Figure 3.33).

Older fetuses also decreased ‘Body touch’ in the ‘Father’ condition (M = 0.46) compared to younger fetuses ‘Control’ (M = 2.31, p = 0.77) (see Figure

3.34). No further effects were found. The means and standard errors can be examined in Table 3.28.

Table 3.28. Means and standard errors (SE) of fetuses ‘Body touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.17	0.25	1.04	0.27		
Control	0.80	0.55	2.31	0.59	1.55	0.40
Mother	1.33	0.47	0.46	0.51	0.90	0.35
Father	1.47	0.51	0.46	0.55	0.96	0.37
Stranger	1.07	0.37	0.92	0.39	1.00	0.27

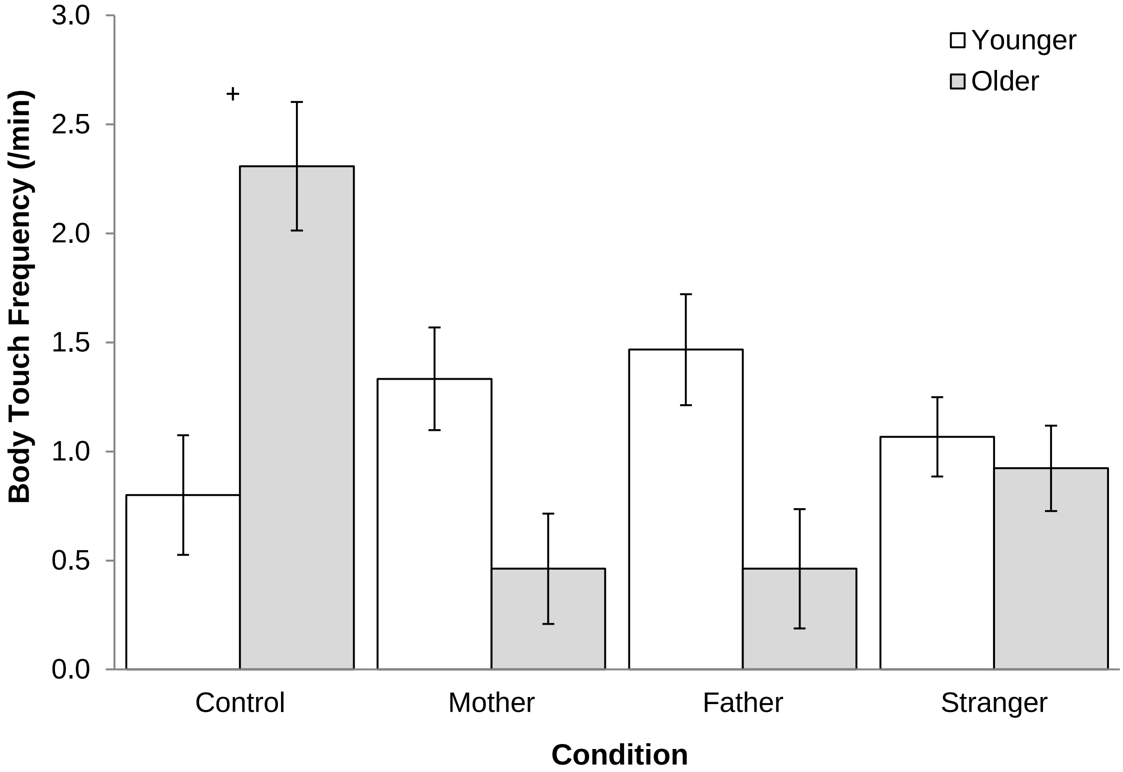

Figure 3.33. Average ‘Body touch’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

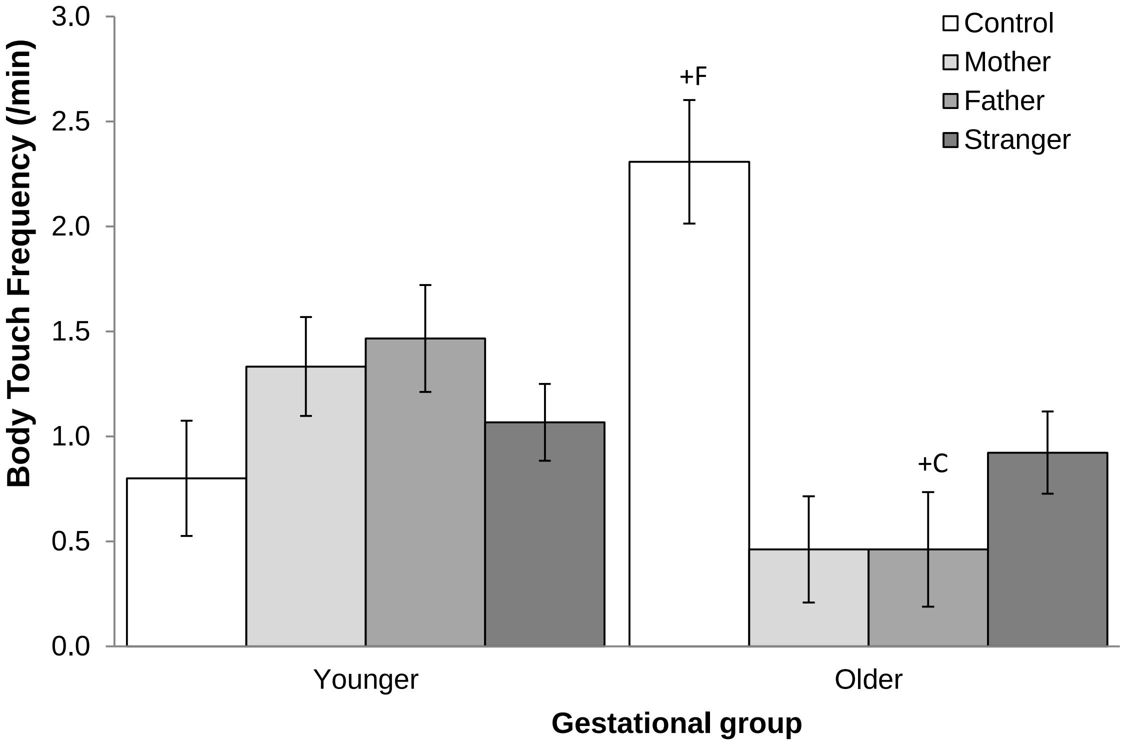

Figure 3.34. Average ‘Body touch’ frequency (in minutes) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Frequency

A mixed ANOVA was conducted to assess differences in ‘Uterus touch’ frequency and GA across the four Conditions (Control, Mother, Father, Stranger). Results indicated a tendency for an interaction between Condition and GA, F (3, 78) = 2.46, p = .069, η_p^2 = .09. No main effect of Condition F (3, 78) = 0.76, p = .523, η_p^2 = .03, or GA F (1, 26) = 0.35, p = .558, η_p^2 = .01, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 4.68, p = .040, η_p^2 = .15 of Condition and GA.

Post-hoc pairwise comparison of the interaction showed that younger fetuses touch the uterus significantly more (M = 1.47; p = .038) more in the ‘Father’ condition compared to older fetuses (M = 0.46). In the ‘Control’ condition younger fetuses (M = 1.33) tend to respond more compared to older fetuses (M = 0.46; p = 0.70) (see Figure 3.35 and 3.36). No further effects were found. The means and standard errors can be examined in Table 3.29.

Table 3.29. Means and standard errors (SE) of fetuses ‘Uterus touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.07	0.21	0.89	0.22		
Control	1.33	0.31	0.46	0.34	0.90	0.23
Mother	0.93	0.59	1.69	0.63	1.31	0.43
Father	1.47	0.31	0.46	0.33	0.96	0.23
Stranger	0.53	0.30	0.92	0.31	0.73	0.21

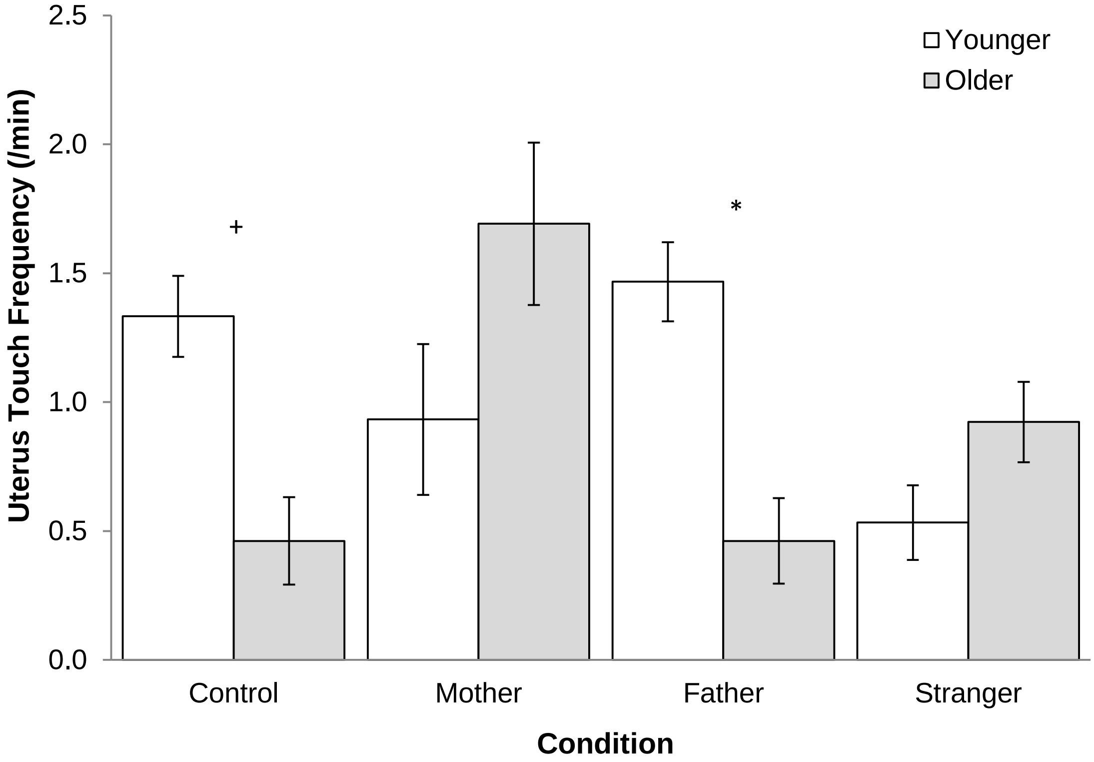

Figure 3.35. Average ‘Uterus touch’ frequency (per minute) including standard errors for all four conditions across gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *<.05).

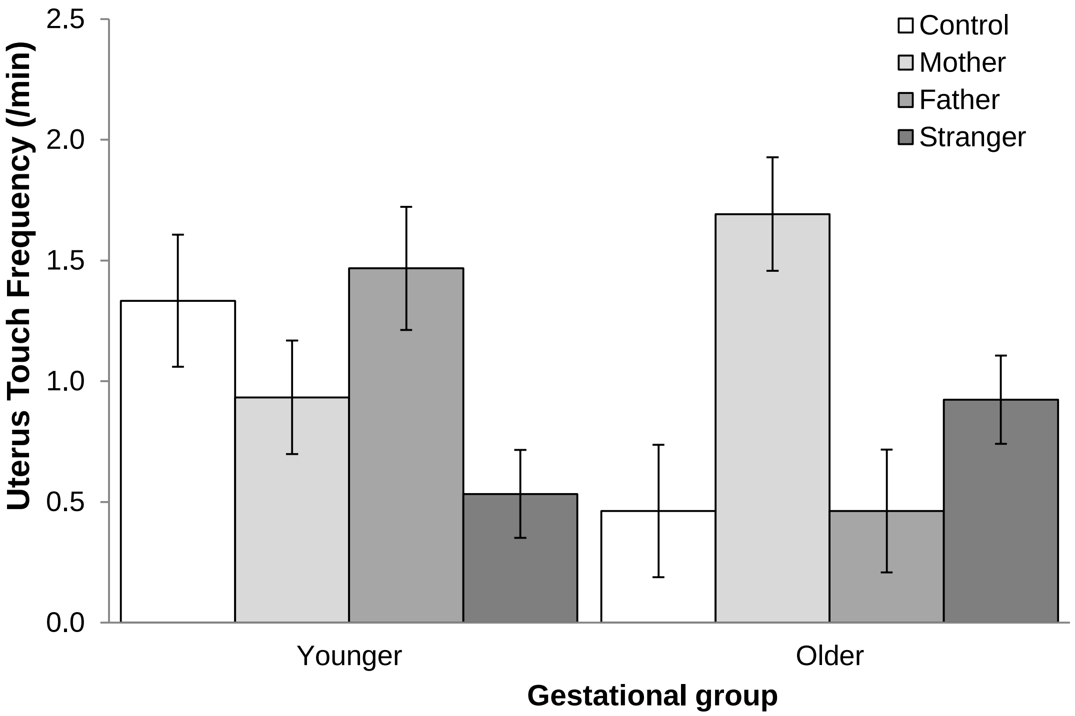

Figure 3.36. Average ‘Uterus touch’ frequency (in minutes) including standard errors for all four conditions between gestational ages (younger and older fetuses).

Mixed-design ANOVA Condition*GA: 'Uterus touch' Duration

A mixed ANOVA was conducted to assess how GA and Conditions (Control, Mother, Father, Stranger) affect the duration of 'Uterus touch'. Results showed a significant interaction between Condition and GA, F (3, 78) = 3.15, p = .030, η_p^2 = .11. No main effects of Condition F (3, 78) = 0.48, p = .694, η_p^2 = .02, or GA F (1, 26) = 0.01, p = .909, $\eta_p^2 < .001$, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 6.50, p = .017, η_p^2 = .20 of Condition and GA.

Post-hoc pairwise comparison of the interaction showed that younger fetuses (M = 27.07) touch the uterus significantly longer in 'Control' compared to older fetuses (M = 1.69, p = .039). Older fetuses tended to touch the uterus longer in 'Stranger' (M = 36.34) compared to 'Control' condition (M = 1.69, p = .058) while younger foetuses showed no such difference (see Figure 3.37).

In the 'Stranger' condition older fetuses (M = 36.34) respond significantly longer compared to younger fetuses (M = 6.87. p = .032) (see Figure 3.38). No further effects were found. The means and standard errors can be examined in

Table 3.30. Means and standard errors (SE) of the duration of fetuses 'Uterus touch' across conditions and gestational ages as well as pairwise comparisons.

Table 3.30.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	19.18	4.39	19.92	4.71		
Control	27.07	7.93	1.69	8.52	14.38	5.82
Mother	21.05	10.17	28.55	10.93	24.80	7.47
Father	21.72	8.59	13.11	9.22	17.41	6.30

Stranger	6.87	8.87	36.34	9.53	21.61	6.51

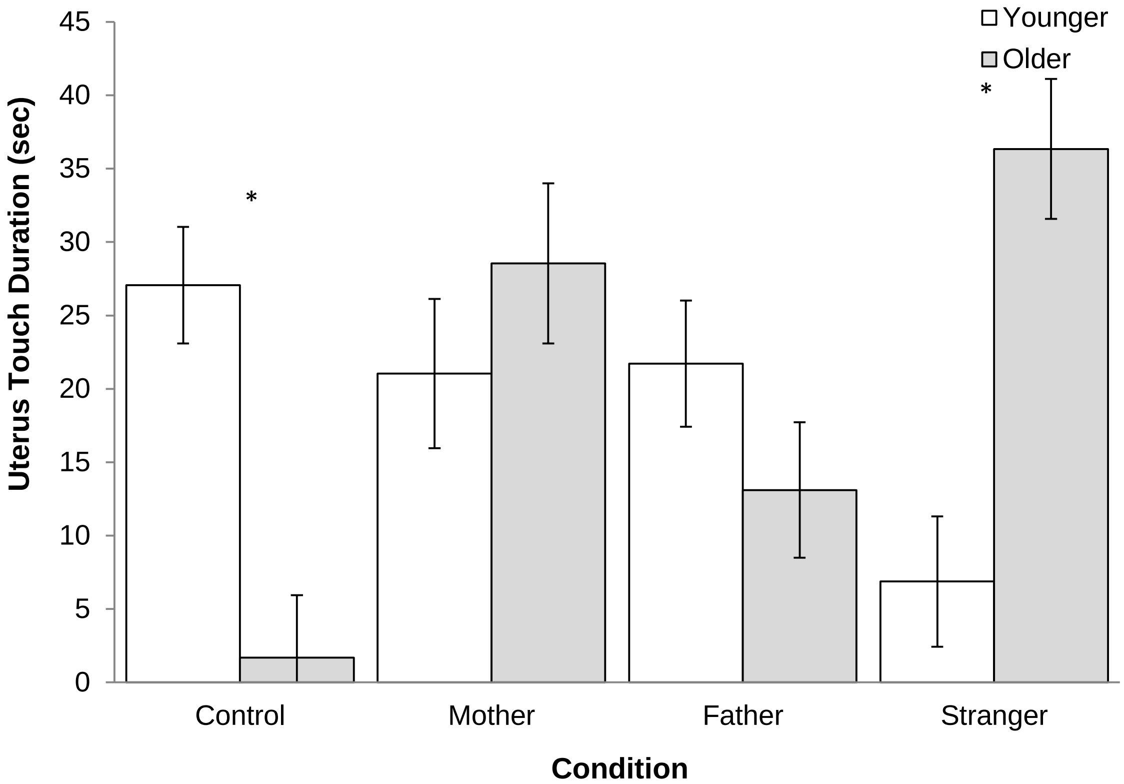

Figure 3.37. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions across gestational ages (younger and older fetuses) (*<.05).

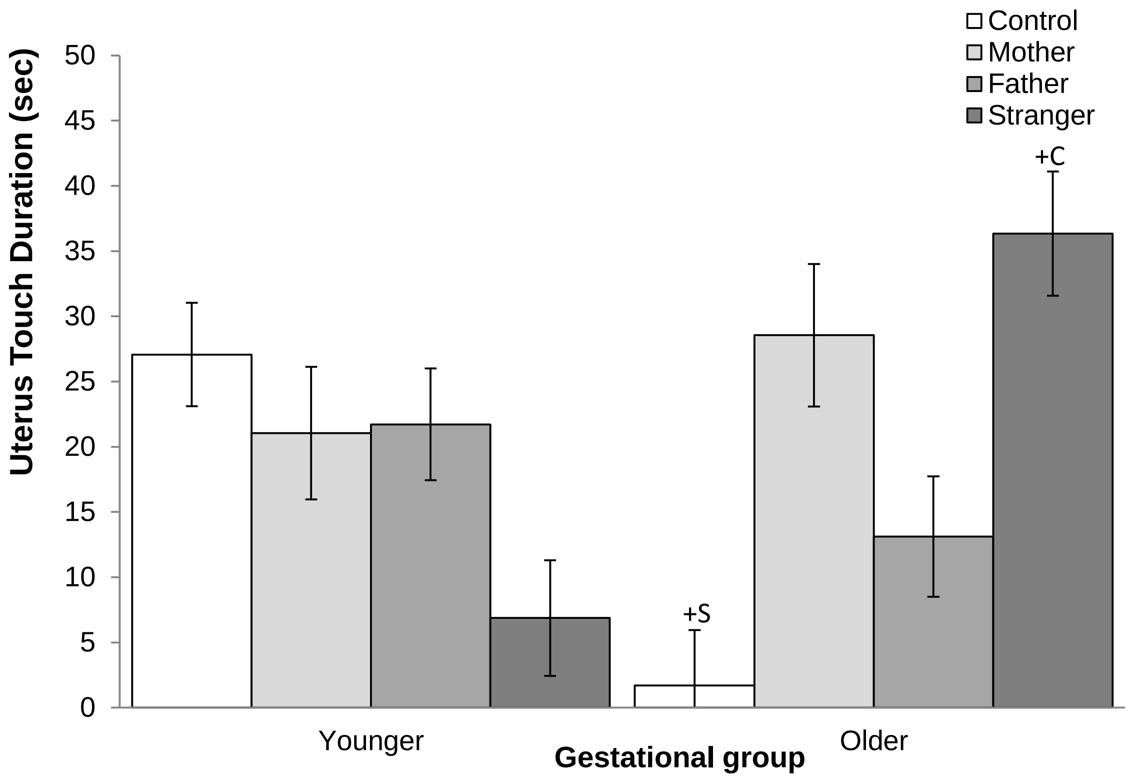

Figure 3.38. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Arms-crossed’ Duration

A mixed-design ANOVA was conducted examine the effect of the Conditions (Control, Mother, Father, Stranger) and GA on the duration of ‘Arms-crossed’ behaviour of the fetus. Results show a significant main effect of GA, F (1, 26) = 6.36, p = .018, η_p^2 = .18. No main effect of Condition F (3, 78) = 1.50, p = .222, η_p^2 = .05, or an interaction F (3, 78) = 1.06, p = .372, η_p^2 = .04, were found.

Post-hoc pairwise comparison of the main effect of GA showed that older fetuses displayed ‘Arms-crossed’ for longer (M = 27.60) than younger fetuses did (M = 8.61; p = .018) (see Figure 3.39). No further effects were found. The means and standard errors can be examined in Table 3.31.

Table 3.31. Means and standard errors (SE) of fetuses 'Arms-crossed' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	8.61	5.13	27.60	5.51		
Control	12.40	10.04	32.57	10.78	22.49	7.37
Mother	7.08	6.86	11.18	7.37	9.13	5.03
Father	6.51	8.46	23.08	9.08	14.80	6.21
Stranger	8.45	10.05	43.59	10.80	26.02	7.37

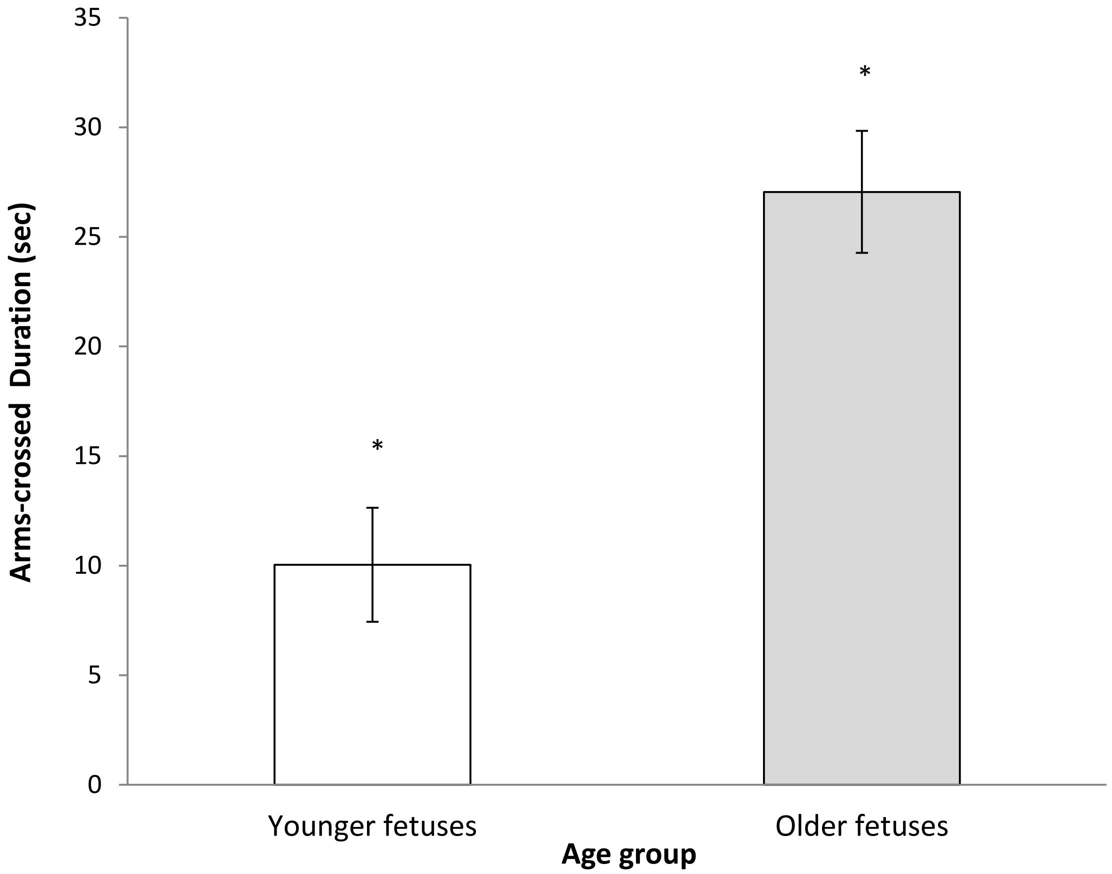

Figure 3.39. Average 'Arms-crossed' duration (seconds) including standard errors for GA (younger and older fetuses) (*< .05).

Mixed-design ANOVA Condition*GA: 'Hand movement' Frequency

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of 'Hand movements'. There is a trend for a main effect of GA, F (1, 26) = 2.96, p = .095, η_p^2 = .10, but no main effect of Condition F (2.20, 57.21) = 0.30, p = .760, η_p^2 = .01, or an interaction F (2.20, 57.21) = 0.30, p = .760, η_p^2 = .01, were found.

Post-hoc pairwise comparison of the main effect of GA showed a difference that younger fetuses (M = 1.47) tended to display more 'Hand movements' compared to older fetuses (M = 0.62; p = .095) (see Figure 3.40). No further effects were found. The means and standard errors can be examined

Table 3.32. Means and standard errors (SE) of fetuses 'Hand movement' frequency across conditions and gestational ages as well as pairwise comparisons.

in Table 3.32.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.47	0.34	0.62	0.36		
Control	1.07	0.45	0.46	0.49	0.76	0.33
Mother	1.87	0.50	0.31	0.54	1.09	0.37
Father	1.33	0.50	0.62	0.54	0.97	0.37
Stranger	1.60	0.89	1.08	0.96	1.34	0.66

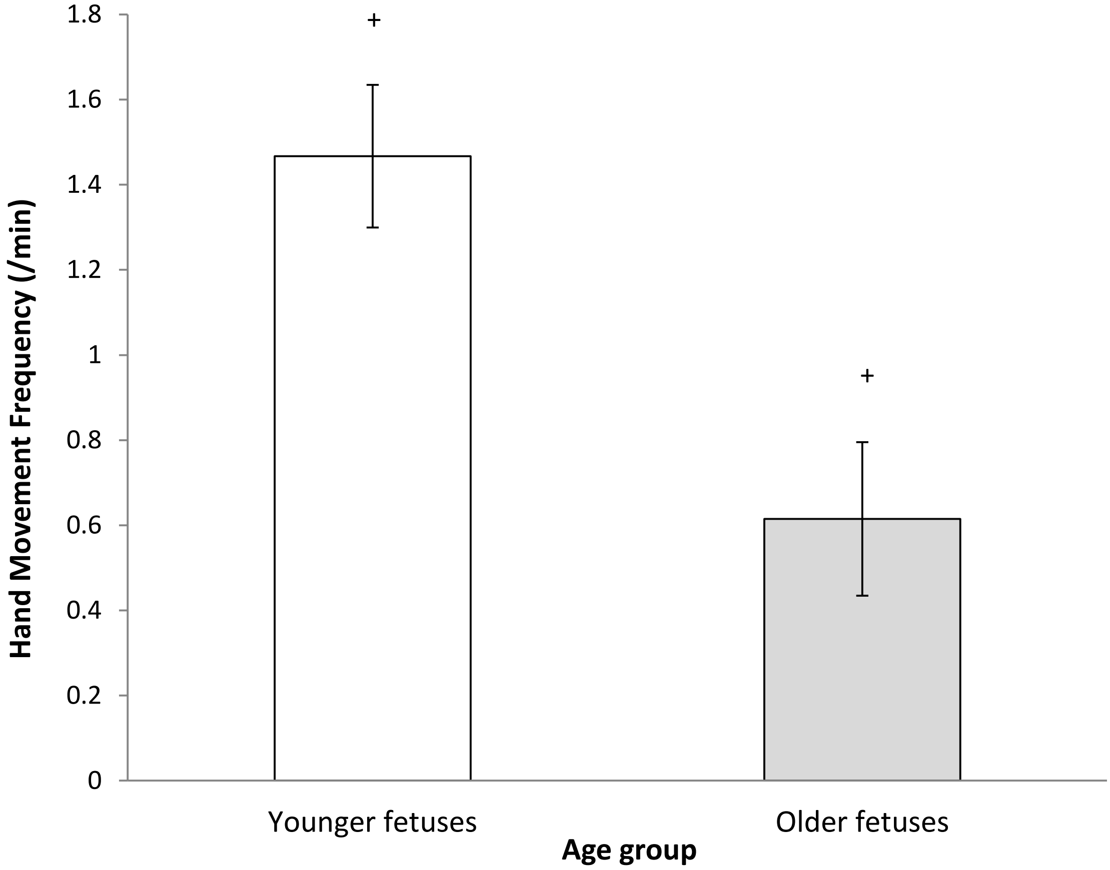

Figure 3.40. Average ‘Hand movement’ frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Hand movement’ Duration

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Hand movements’. Results indicate a trend for a main effect of GA, F (1, 26) = 3.86, p = .060, η_p^2 = .13. No main effect of Condition F (1.30, 33.86) = 2.18, p = .144, η_p^2 = .08, or an interaction F (1.30, 33.86) = 1.96, p = .167, η_p^2 = .07, were found.

Post-hoc pairwise comparison of the main effect of GA showed that younger fetuses (M = 6.73) tended to display longer ‘Hand movements’ compared to older fetuses (M = 1.09, p = .060) (see Figure 3.41). No further effects were found. The means and standard errors can be examined in Table 3.33.

Table 3.33. Means and standard errors (SE) of fetuses 'Hand movement' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	6.73	1.96	1.09	2.10		
Control	2.71	1.09	0.41	1.17	1.56	0.80
Mother	17.76	6.53	1.28	7.01	9.57	4.79
Father	5.07	2.92	1.31	3.13	3.19	2.14
Stranger	1.40	0.98	1.28	1.10	1.34	0.72

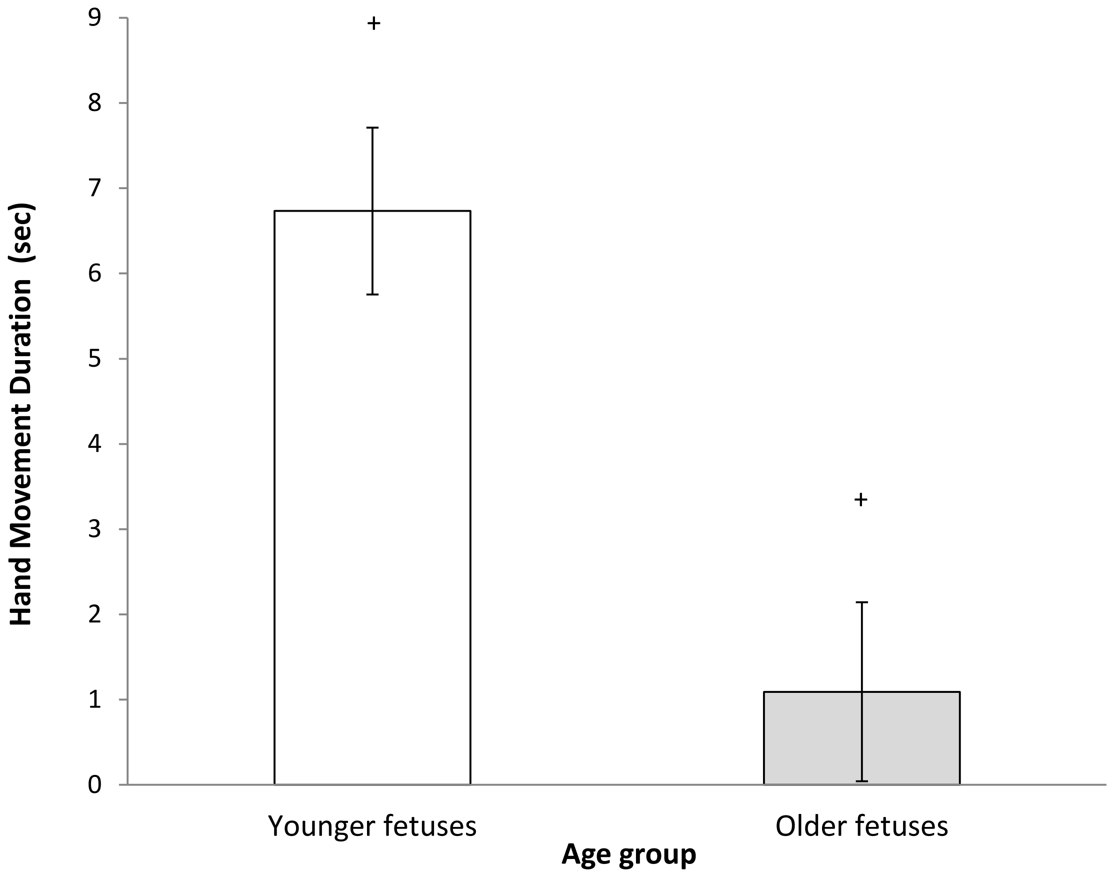

Figure 3.41. Average 'Hand movement' duration (in seconds) including standard errors for GA (younger and older fetuses) (*< .05).

Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency

A mixed-design ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Face press’. The Condition main effect indicates a trend, *F* (3, 78) = 2.28, *p* = .086, η_p^2 = .08. Neither main effects of GA *F* (1, 26) = 1.22, *p* = .280, η_p^2 = .05, nor an interaction *F* (3, 78) = 0.66, *p* = .579, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant quadratic trend *F* (1, 26) = 7.67, *p* = .010, η_p^2 = .23 of Condition, indicating an increase from ‘Control’ (M = 0.41) over ‘Mother’ (M = 0.70) to ‘Father’ (M = 0.93) followed by a decrease to ‘Stranger’ (M = 0.56).

Post-hoc pairwise comparison of the main effect of Condition showed a tendency between ‘Control’ and ‘Father’ conditions, fetuses showed a higher frequency of Face press in ‘Father’ (M = 0.93) compared to ‘Control’ conditions (M = 0.41, *p* = .077) with no other significant differences between the other Conditions (see Figure 3.42). No further effects were found. The means and standard errors can be examined in Table 3.34.

Table 3.34. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.80	0.19	0.50	0.20		
Control	0.67	0.21	0.15	0.22	0.41	0.15
Mother	0.93	0.29	0.46	0.31	0.70	0.21
Father	0.93	0.28	0.92	0.29	0.93	0.20
Stranger	0.67	0.24	0.46	0.26	0.56	0.18

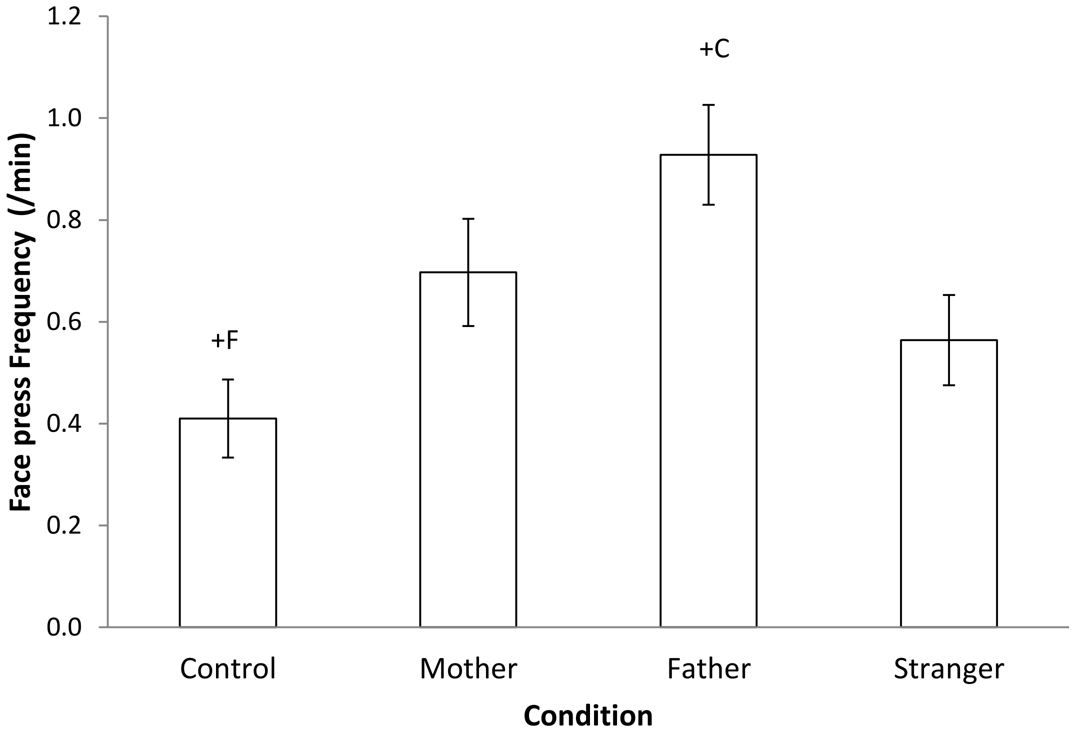

Figure 3.42. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Face press’ Duration

A mixed-design ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Face press’. The Condition main effect indicates a trend, F (3, 78) = 2.37, p = .077, η_p^2 = .08. No main effect of GA F (1, 26) = 1.03, p = .319, η_p^2 = .04, or an interaction F (3, 78) = 0.55, p = .651, η_p^2 = .02, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 6.09, p = .021, η_p^2 = .19, of Condition. Overall, an increase is produced by the means from ‘Control’ (M = 20.51), over ‘Mother’ (M = 30.67), to the ‘Father’ condition (M = 46.41). However, the ‘Stranger’ condition has a somewhat lower mean (M = 28.21) producing the quadratic trend.

Post-hoc pairwise comparison of the main effect of Condition showed that fetuses had a tendency for longer Face press in the ‘Father’ (M = 46.41) than in the ‘Control’ conditions (M = 20.51, p = .077) (see Figure 3.43). No other significant differences were found between conditions. No further effects were found. The means and standard errors can be examined in Table 3.35.

Table 3.35. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	37.90	8.65	25.00	9.21		
Control	33.33	10.45	7.69	11.22	20.51	7.67
Mother	38.25	12.03	23.08	12.92	30.67	8.83
Father	46.67	13.36	46.15	14.35	46.41	9.81
Stranger	33.33	12.03	23.08	12.92	28.21	8.83

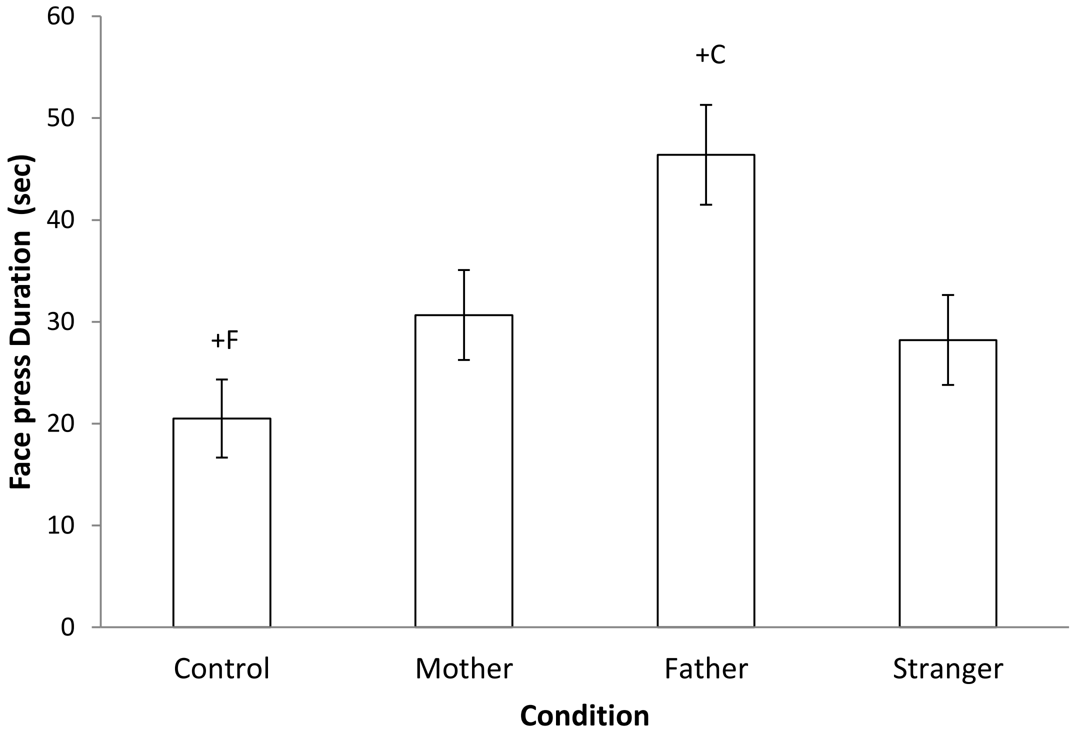

Figure 3.43. Average ‘Face press’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

0-30s Interval analysis combined

Mixed-design ANOVA Condition*GA: ‘Self-touch’ Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Self-touch’. Results showed no main effect of Condition F (3, 78) = 0.31, p = .821, η_p^2 = .01, or main effect of GA F (1, 26) = 0.97, p = .334, η_p^2 = .04. Results revealed a tendency for an interaction between Condition and GA, F (3, 78) = 2.30, p = .084, η_p^2 = .08. In support of this polynomial contrasts of the interaction show a tendency for a linear trend of Condition and GA F (1, 26) = 4.00, p = .056, η_p^2 = .13, and a quadratic trend F (1, 26) = 3.36, p = .078, η_p^2 = .11.

Post-hoc pairwise analysis of the interaction between Condition and GA revealed no further effects (see Figure 3.44 and 3.45). The means and standard errors can be examined in Table 3.36.

Table 3.36. Means and standard errors (SE) of fetuses 'Self-touch' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.67	0.43	3.05	0.46		
Control	2.80	0.96	4.92	1.03	3.86	0.70
Mother	3.60	0.77	2.67	0.83	3.13	0.57
Father	4.53	1.01	2.15	1.09	3.34	0.74
Stranger	3.73	0.67	2.46	0.72	3.10	0.49

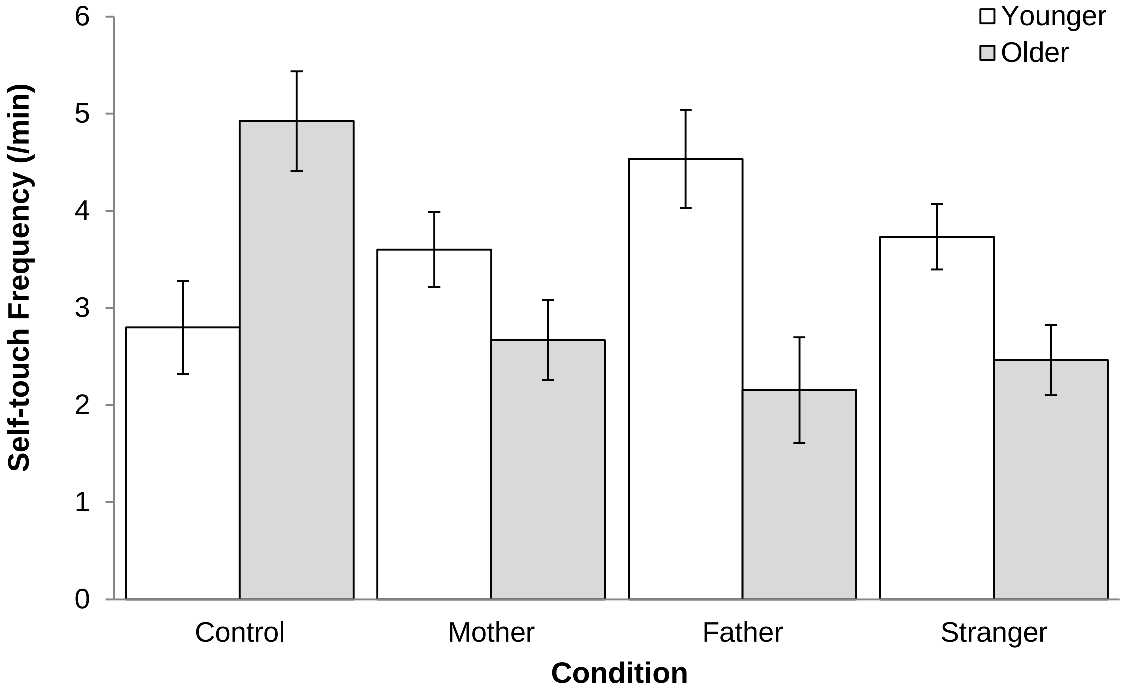

Figure 3.44. Average 'Self-touch' frequency (per minute) including standard errors for each condition.

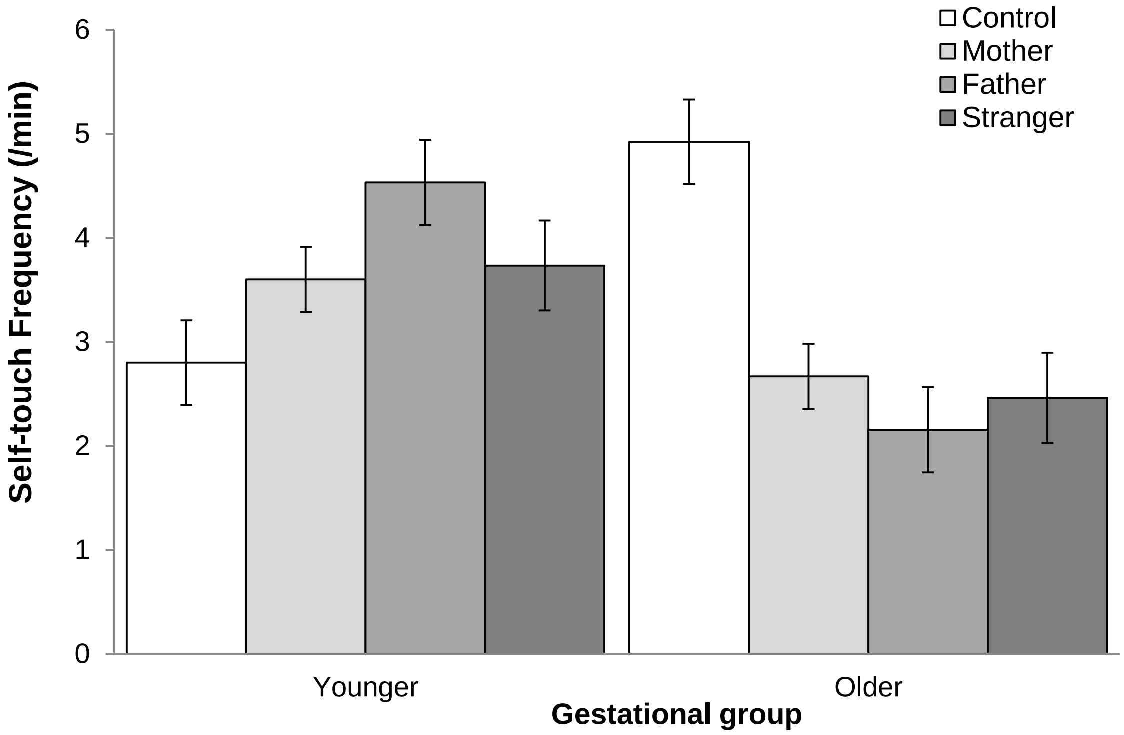

Figure 3.45. Average 'Self-touch' frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses).

Mixed-design ANOVA Condition*GA: 'Self-touch' Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Self-touch'. Results showed a significant interaction between Condition and GA, F (3, 78) = 2.77, p = .047, η_p^2 = .10, but no main effect of Condition F (3, 78) = 1.11, p = .349, η_p^2 = .04, and no main effect of GA F (1, 26) = 0.45, p = .507, η_p^2 = .02. In support of this polynomial contrasts of the interaction show a significant linear trend of Condition and GA F (1, 26) = 4.92, p = .036, η_p^2 = .16, and a quadratic trend F (1, 26) = 3.91, p = .059, η_p^2 = .13.

Post-hoc pairwise comparison of the interaction between Condition and GA showed a significant difference in 'Control' for younger and older fetuses, with older fetuses (M = 9.56) engaging in significantly longer 'Self-touch' compared to younger fetuses (M = 7.06, p = .047). A tendency can be observed in 'Stranger', with younger fetuses (M = 8.96) engaging in longer 'Self-touch' than older fetuses (M = 6.37, p = .059) (see Figure 3.46). A further tendency can be observed for older fetuses engaging in longer ‘Self-touch’ in control (M = 9.56) compared to ‘Stranger’ (M = 8.96, p = .098) (see Figure 3.47). No further effects were found. The means and standard errors can be examined in Table

Table 3.37. Means and standard errors (SE) of fetuses ‘Self-touch’ duration across conditions and gestational ages as well as pairwise comparisons.

3.37.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.29	0.42	7.71	0.45		
Control	7.06	0.82	9.56	0.88	8.31	0.60
Mother	6.65	1.10	6.35	1.18	6.50	0.80
Father	6.49	0.92	8.57	0.99	7.53	0.67
Stranger	8.96	0.90	6.37	0.96	7.66	0.66

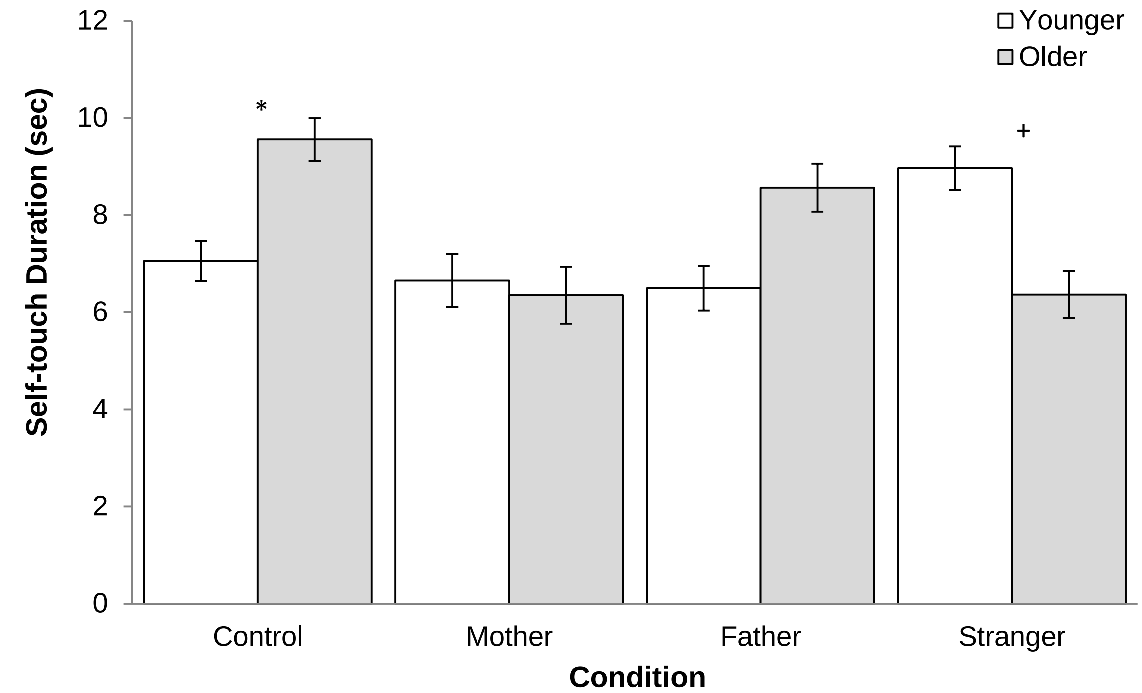

Figure 3.46. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *<.05).

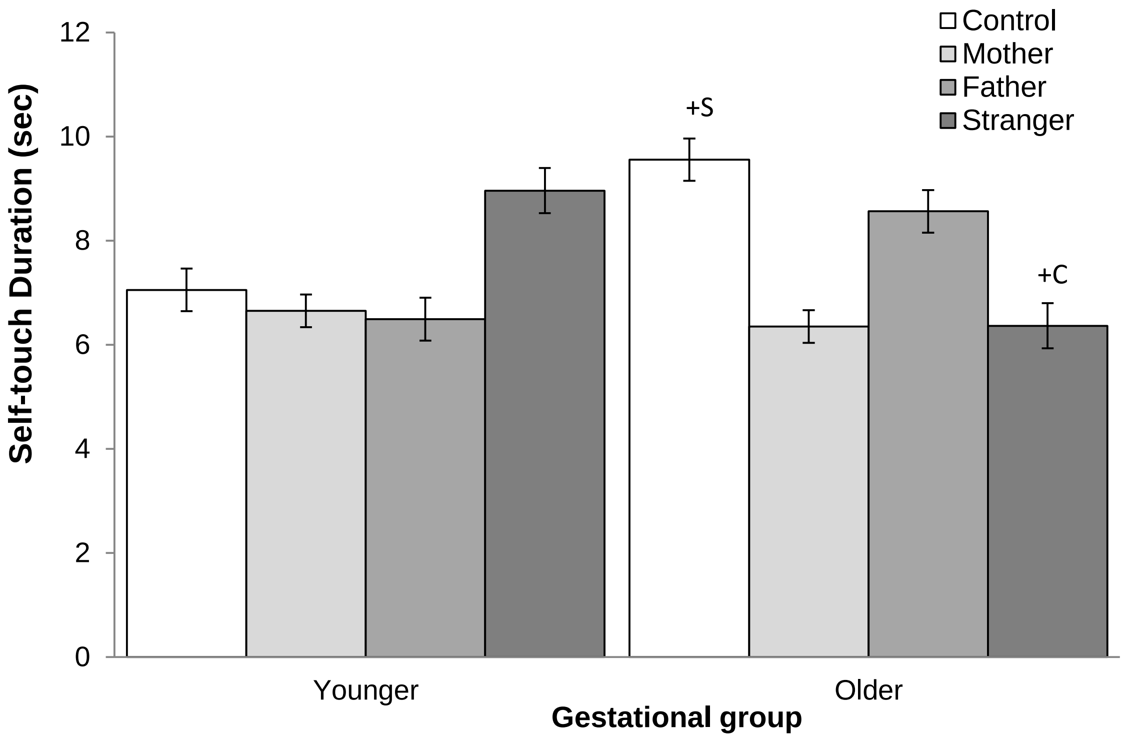

Figure 3.47. Average ‘Self-touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Inactivity/Resting’ Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Inactivity/Resting’. Results showed a marginally significant main effect of Condition, F (3, 78) = 2.40, p = .074, η_p^2 = .09. A further tendency of main effect of GA F (1, 26) = 3.57, p = .070, η_p^2 = .12 was revealed. No interaction effect F (3, 78) = 1.53, p = .215, η_p^2 = .06 was found. In support of this polynomial contrasts indicated a marginally significant quadratic trend F (1, 26) = 3.69, p = .066, η_p^2 = .12 of Condition, indicating a decrease from ‘Control’ (M = 4.14) to ‘Mother’ (M = 2.16), followed by an increase to ‘Father’ (M = 3.61) and ‘Stranger’ (M = 5.19).

Post-hoc pairwise comparison of the Condition main effect showed a tendency between ‘Mother’ and ‘Stranger’ with a higher duration of ‘Inactivity/Resting’ in ‘Stanger’ (M = 5.19) compared to ‘Mother’ (M = 2.16, p = .052) (see Figure 3.48).

Post-hoc pairwise comparison of the main effect of GA showed a significant difference with older fetuses (M = 4.62) displaying longer ‘Inactivity/Resting’ compared to younger fetuses (M = 2.93, p = .070) (see Figure 3.49). No further effects were found. The means and standard errors can be examined in Table 3.38.

Table 3.38. Means and standard errors (SE) of fetuses ‘Inactivity/Resting’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.93	0.61	4.62	0.66		
Control	2.71	1.18	5.57	1.27	4.14	0.87
Mother	2.44	1.02	1.89	1.09	2.16	0.75
Father	3.38	1.23	3.85	1.33	3.61	0.91
Stranger	3.19	1.11	7.20	1.19	5.19	0.81

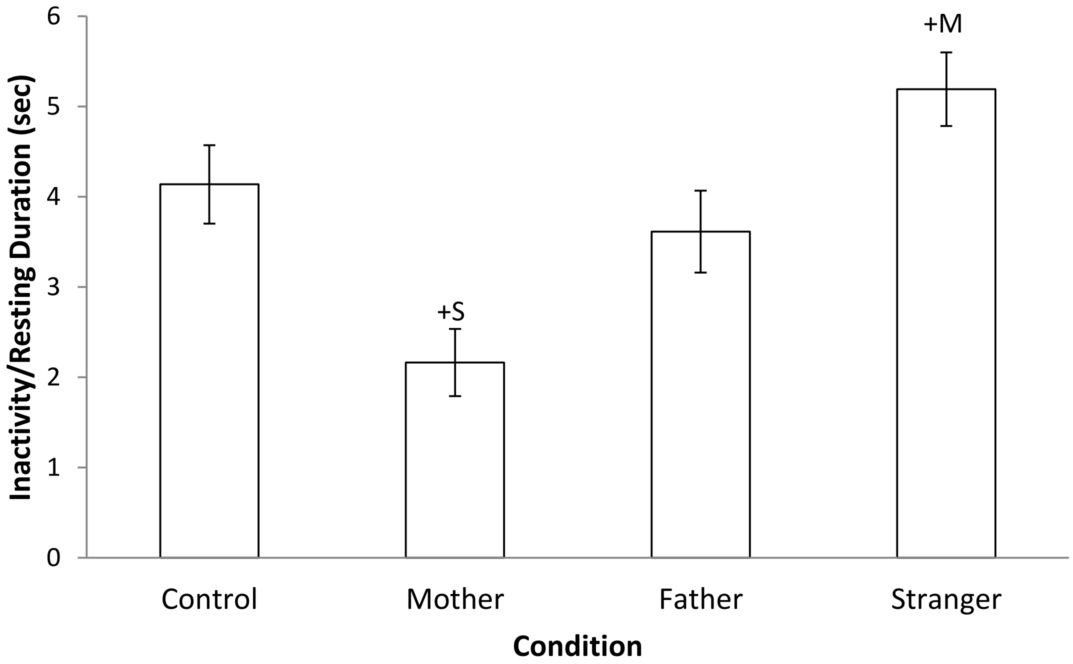

Figure 3.48. Average ‘Inactivity/Resting’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

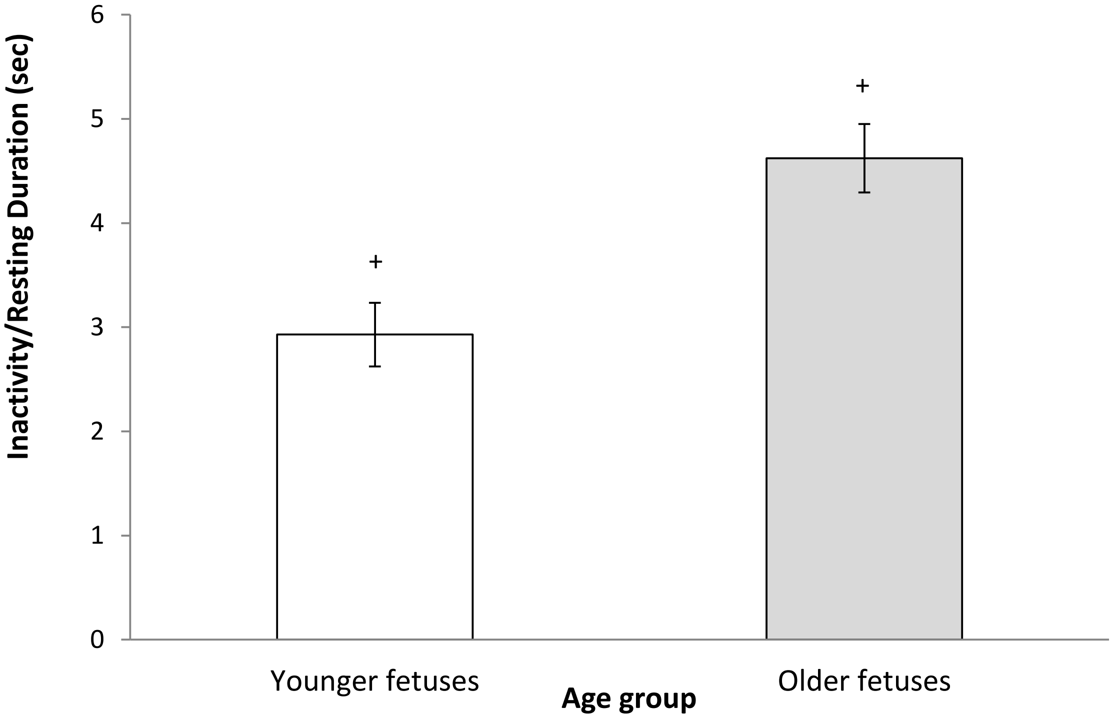

Figure 3.49. Average ‘Inactivity/Resting’ duration (in seconds) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

0-60s Interval

Mixed-design ANOVA Condition*GA: ‘Body touch’ Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of ‘Body touch’. Results showed no main effect of Condition F (3, 78) = 0.52, p = .667, η_p^2 = .02, no significant main effect of GA F (1, 26) = 0.27, p = .605, η_p^2 = .01, but a tendency for an interaction between Condition and GA, F (3, 78) = 2.32, p = .082, η_p^2 = .08. In support of this tendency polynomial contrasts of the interaction showed a significant quadratic trend of Condition and GA F (1, 26) = 6.95, p = .014, η_p^2 = .21.

Post-hoc pairwise comparison of the interaction between Condition and GA show that older fetuses tended to display more ‘Body touch’ in ‘Control’ (M = 1.39) compared to ‘Father’ condition (M = 0.39; p = .085) (see Figure 3.50 and 3.51). No further effects were found. The means and standard errors can be examined in Table 3.39.

Table 3.39. Means and standard errors (SE) of fetuses' 'Body touch' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.88	0.20	0.73	0.21		
Control	0.67	0.33	1.39	0.35	1.03	0.24
Mother	1.13	0.33	0.39	0.36	0.76	0.24
Father	0.93	0.32	0.39	0.34	0.66	0.24
Stranger	0.80	0.31	0.77	0.33	0.79	0.23

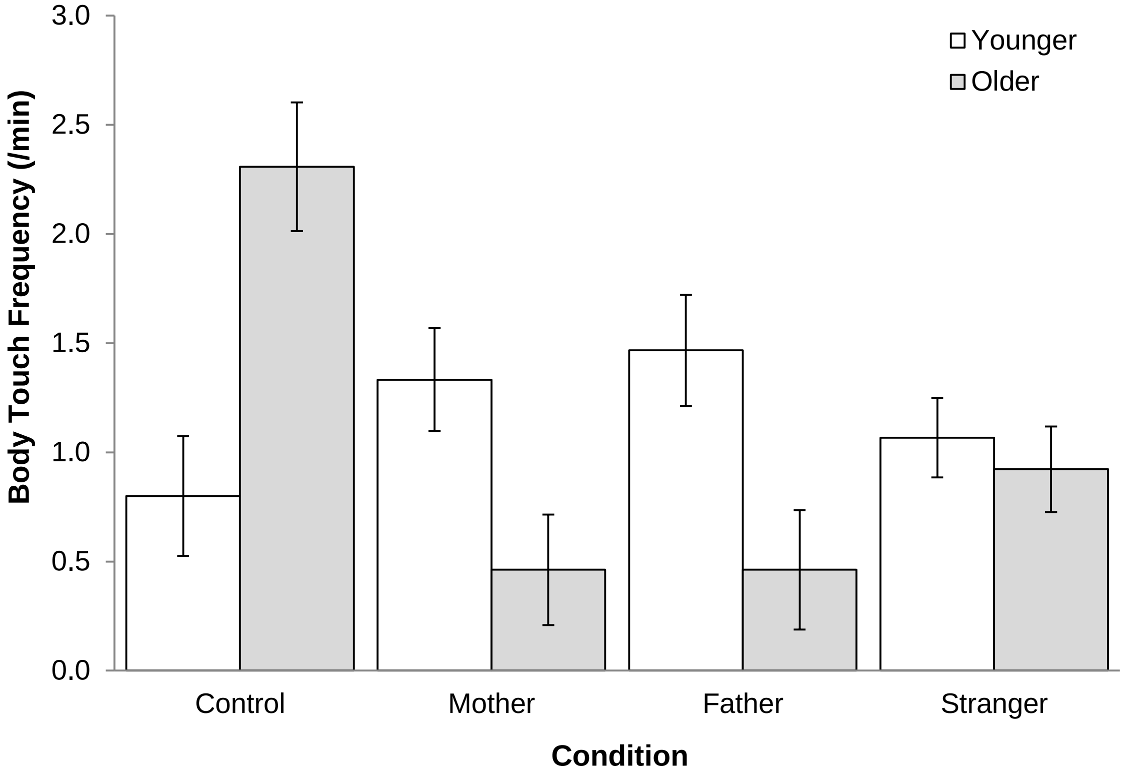

Figure 3.50. Average 'Body touch' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

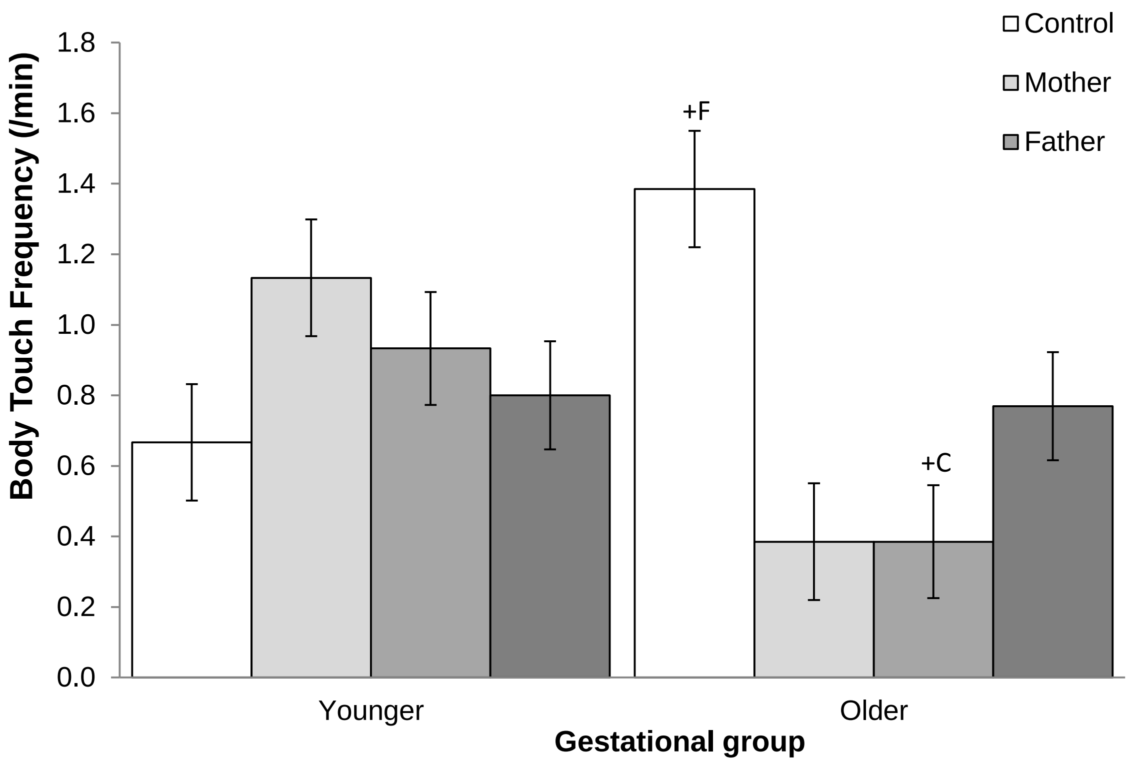

Figure 3.51. Average 'Body touch' frequency (in minutes) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Uterus touch' Frequency

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Uterus touch'. Results indicated a tendency for a main effect of GA F (1, 26) = 3.50, p = .073, η_p^2 = .12. No main effect of Condition F (3, 78) = 0.85, p = .473, η_p^2 = .03, or an interaction F (3, 78) = 0.96, p = .417, η_p^2 = .04, were found.

Post-hoc pairwise comparison of the main effect of GA showed that younger fetuses (M = 0.98) tend to touch the uterus more compared to older fetuses (M = 0.54, p = .073) (see Figure 3.52). No further effects were found. The means and standard errors can be examined in Table 3.40.

Table 3.40. Means and standard errors (SE) of fetuses ‘Uterus touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.98	0.16	0.54	0.17		
Control	0.93	0.23	0.31	0.24	0.62	0.17
Mother	1.00	0.40	1.08	0.43	1.04	0.29
Father	1.20	0.29	0.31	0.31	0.75	0.21
Stranger	0.80	0.26	0.46	0.28	0.63	0.19

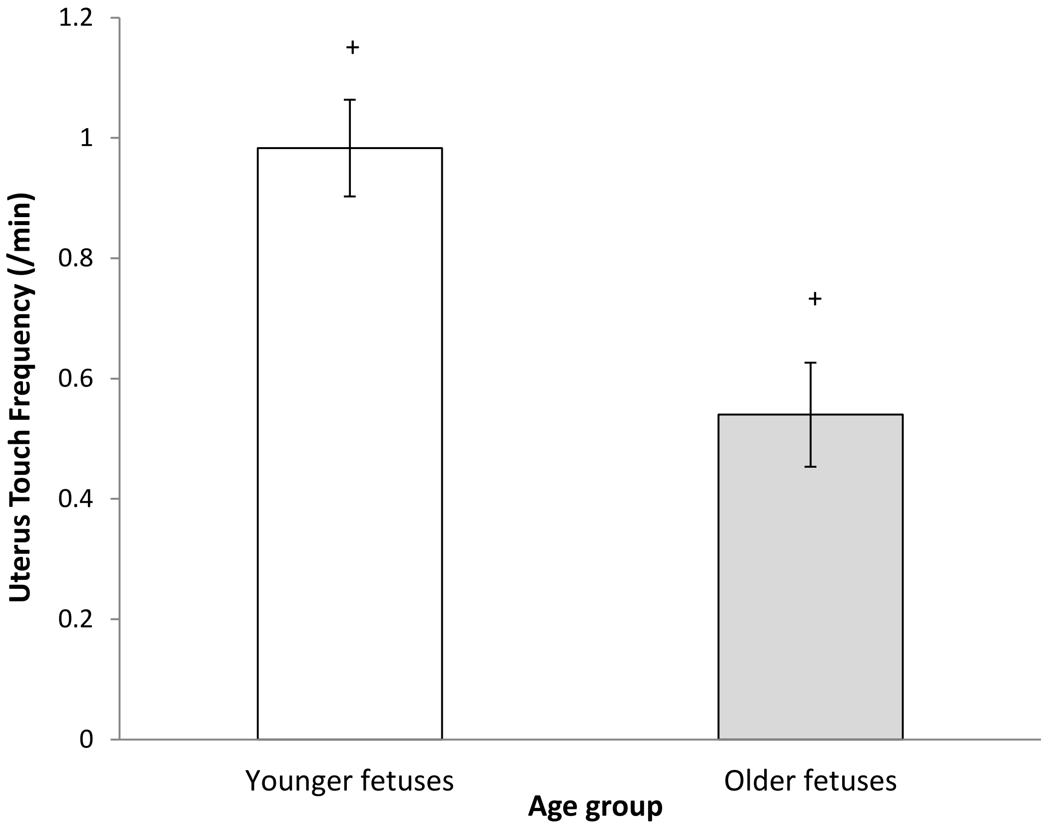

Figure 3.52. Average ‘Uterus touch’ frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Duration

A mixed ANOVA was conducted to assess the effects of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Uterus touch’. Results showed a significant interaction between Condition and GA, F (3, 78) = 3.17, p = .029, η_p^2 = .11. No main effects of Condition F (3, 78) = 1.14, p = .338, η_p^2 = .04, or GA F (1, 26) = 0.01, p = .947, η_p^2 < .001, were found. In support of this polynomial contrasts indicated a significant linear trend F (1, 26) = 6.69, p = .016, η_p^2 = .21, of Condition and GA.

Post-hoc pairwise comparison of the interaction showed that younger fetuses touch the uterus significantly longer (M = 26.82) compared to older fetuses (M = 1.00, p = .030) in the ‘Control’ condition. In the ‘Stranger’ condition older fetuses respond significantly longer (M = 30.10) compared to younger fetuses (M = 4.69, p = .033). Older fetuses tend to touch the uterus longer during ‘Mother’ (M = 32.99) compared to ‘Control’ condition (M = 1.00, p = .095). Also, older foetuses had a tendency to touch the uterus for longer in the ‘Stranger’ (M = 30.10) compared to the ‘Control’ condition (M = 1.00, p = .097) (see Figures 3.53 and 3.54). No further effects were found. The means and standard errors can be examined in Table 3.41.

Table 3.41. Means and standard errors (SE) of fetuses 'Uterus touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	19.13	4.46	19.56	4.79		
Control	26.82	7.68	1.00	8.25	13.91	5.63
Mother	24.66	10.26	32.99	11.02	28.83	7.53
Father	20.33	8.02	14.16	8.62	17.25	5.89
Stranger	4.69	7.70	30.10	8.27	17.39	5.65

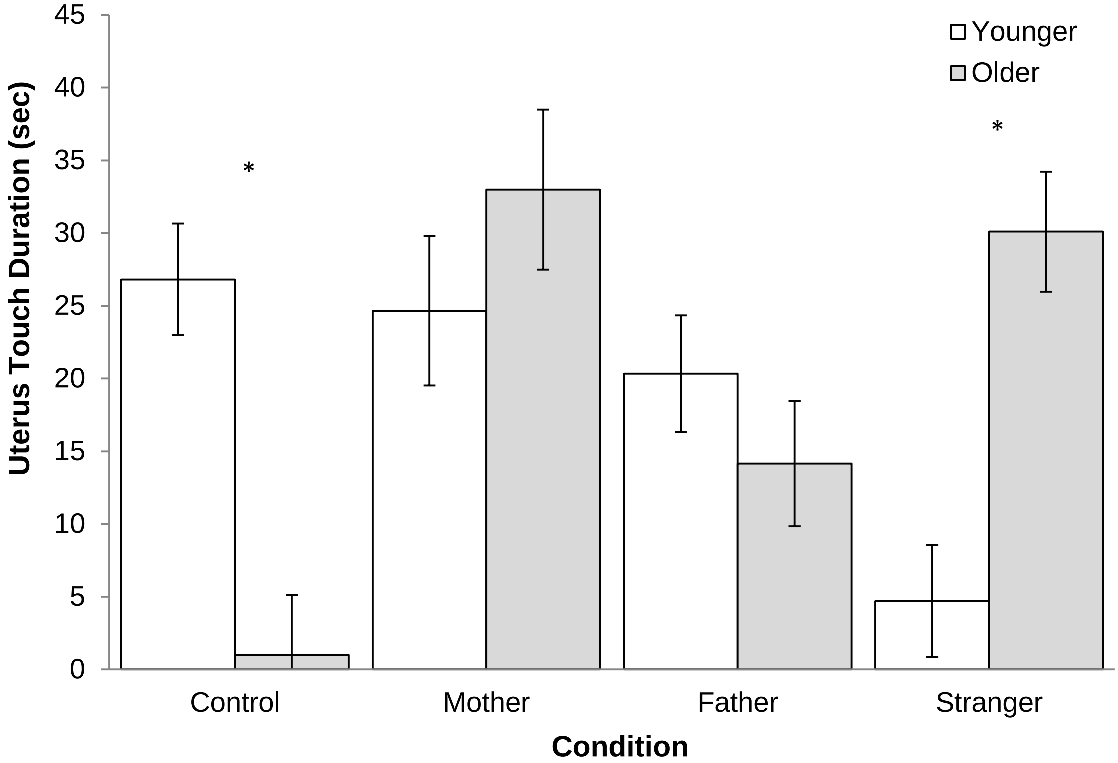

Figure 3.53. Average 'Uterus touch' duration (in seconds) including standard errors for all four conditions across gestational ages (younger and older fetuses) (*<.05).

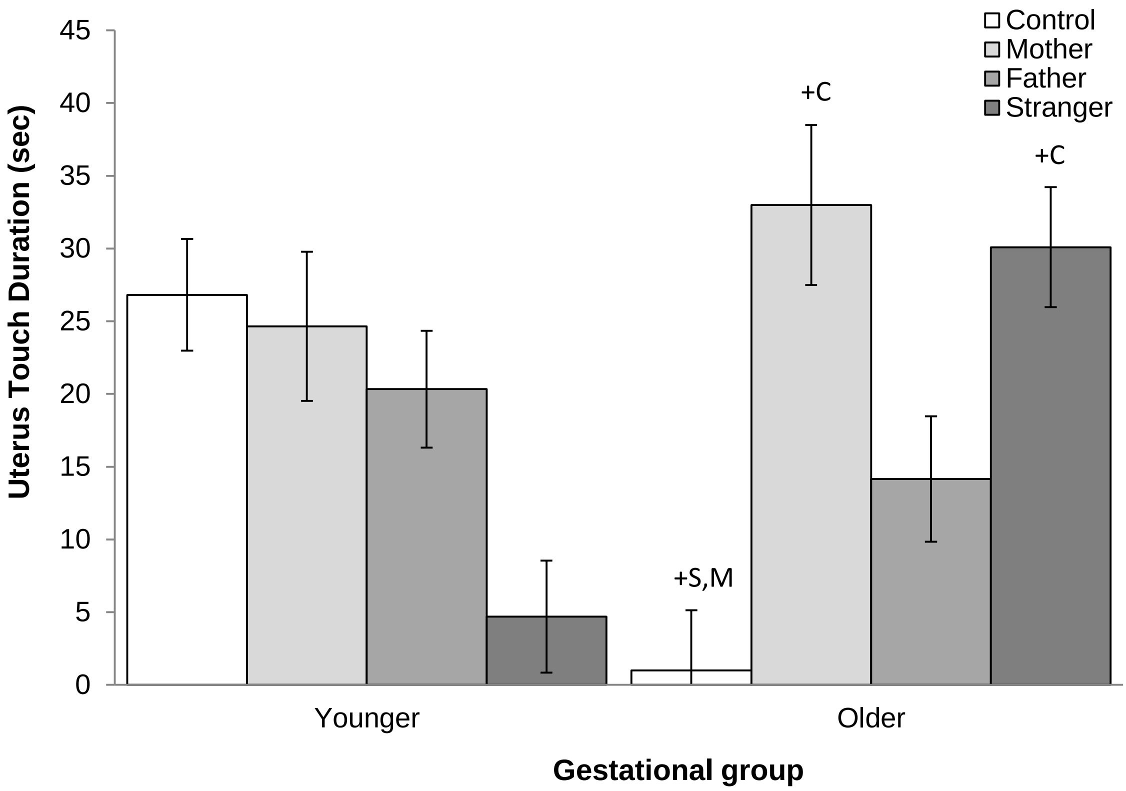

Figure 3.54. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Arms-crossed’ Duration

A mixed-design ANOVA was conducted, to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Arms-crossed’ movements. Results indicate a significant main effect of GA, F (1, 26) = 4.99, p = .034, η_p^2 = .16. No main effect of Condition F (3, 78) = 1.88 p = .201, η_p^2 = .06, or an interaction F (3, 78) = 1.73, p = .168, η_p^2 = .06, were found.

Post-hoc pairwise comparison of the main effect of GA showed that older fetuses displaying longer ‘Arms-crossed’ (M = 27.05) compared to younger fetuses (M = 10.04, p = .034) (see Figure 3.55). No further effects were found. The means and standard errors can be examined in Table 3.42.

Table 3.42. Means and standard errors (SE) of fetuses 'Arms-crossed' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	10.04	5.19	27.05	5.58		
Control	12.18	9.80	31.67	10.52	21.93	7.19
Mother	8.74	6.16	8.35	6.61	8.55	4.52
Father	11.72	9.02	23.56	9.69	17.64	6.62
Stranger	7.53	9.54	44.63	10.25	26.08	7.00

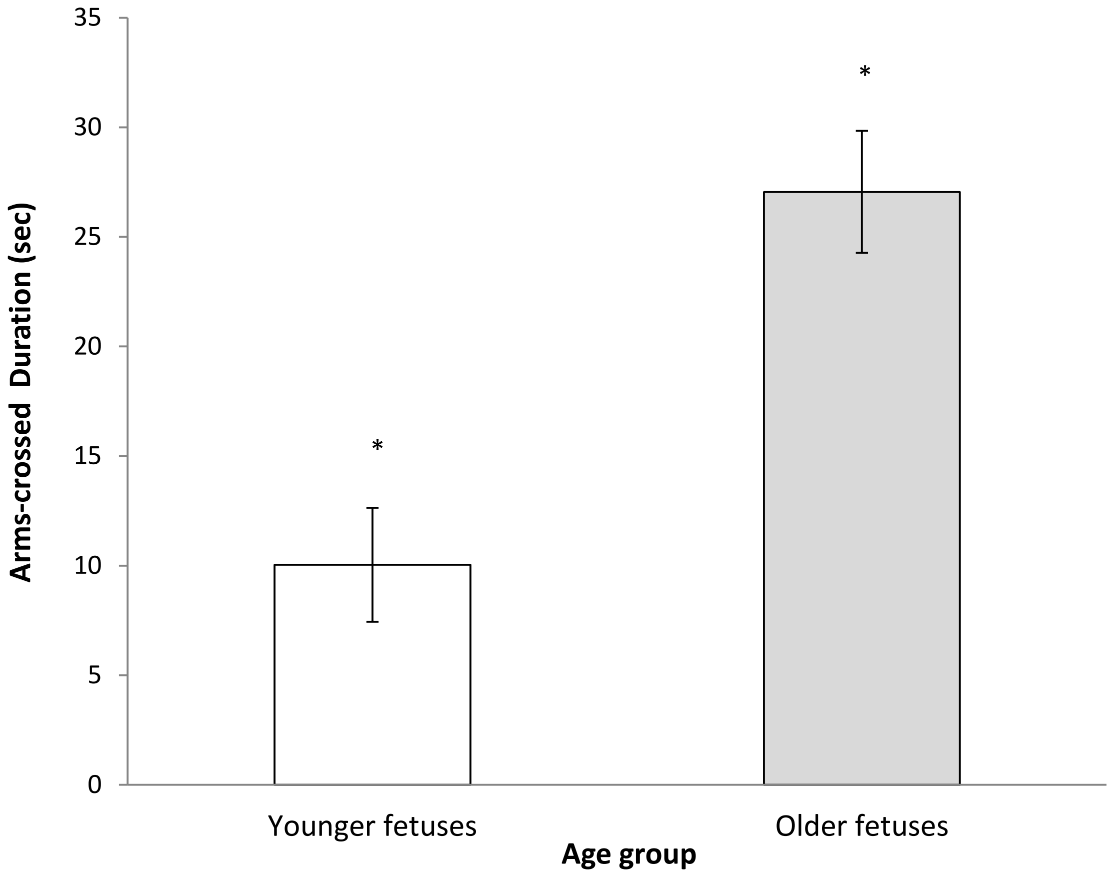

Figure 3.55. Average 'Arms-crossed' duration (in seconds) including standard errors for GA (younger and older fetuses) (*< .05).

Mixed-design ANOVA Condition*GA: 'Face press' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration 'Face press'. The main effect of Condition indicates a trend, *F* (3, 78) = 2.19, *p* = .096, η_p^2 = .08. No main effects of GA *F* (1, 26) = 0.95, *p* = .338, η_p^2 = .04, or an interaction *F* (3, 78) = 0.65, *p* = .584, η_p^2 = .02, were found. In support of this polynomial contrasts indicated a significant quadratic trend *F* (1, 26) = 5.26, *p* = .030, η_p^2 = .17, of Condition. Overall, an increase is produced by the means from 'Control' (M = 20.95), over 'Mother' (M = 29.71) to the 'Father' condition (M = 45.61). However, the 'Stranger' condition has a somewhat lower mean (M = 28.21) producing the quadratic trend.

Post-hoc pairwise comparison of the Condition main effect showed a tendency for a longer duration of 'Face press' in 'Father' (M = 45.61) compared to 'Control' conditions (M = 20.95, *p* = .082) (see Figure 3.56). No other significant differences and further effects were found. The means and standard errors can be examined in Table 3.43.

Table 3.43. Means and standard errors (SE) of fetuses 'Face press' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	37.24	8.54	25.00	9.17		
Control	34.22	10.36	7.69	11.13	20.95	7.60
Mother	36.35	11.89	23.08	12.77	29.71	8.73
Father	45.07	13.17	46.15	14.14	45.61	9.66
Stranger	33.33	12.03	23.08	12.92	28.21	8.83

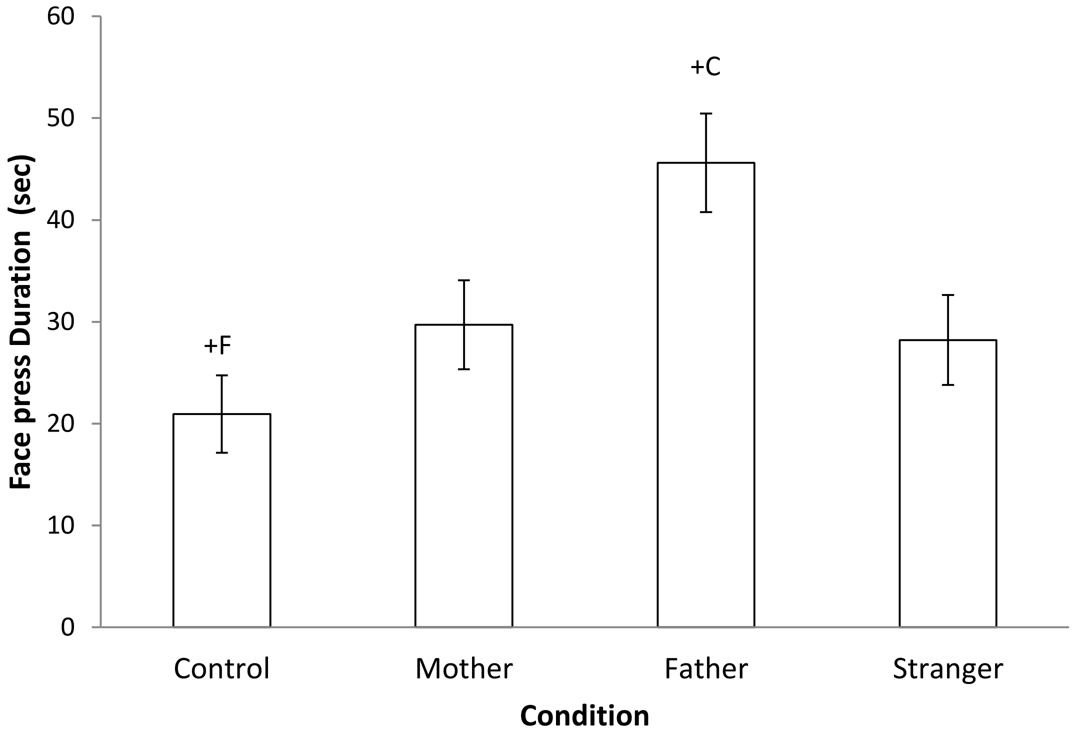

Figure 3.56. Average ‘Face press’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Head movement’ Frequency

A mixed ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of ‘Head movement’. Results indicated a tendency for a main effect of GA F (1, 26) = 3.28, p = .082, η_p^2 = .11. No main effect of Condition F (3, 78) = 1.39, p = .254, η_p^2 = .05, or an interaction F (3, 78) = 0.65, p = .564, η_p^2 = .02, were found.

Post-hoc pairwise comparison of the main effect of GA showed that younger fetuses tend to move the head more (M = 4.28) compared to older fetuses (M = 2.81, p = .082) (see Figure 3.57). No further effects were found. The means and standard errors can be examined in Table 3.44.

Table 3.44. Means and standard errors (SE) of fetuses 'Head movement' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	4.28	0.56	2.81	0.60		
Control	3.80	0.83	2.08	0.89	2.94	0.61
Mother	5.87	1.10	3.21	1.18	4.54	0.81
Father	4.33	0.77	3.02	0.82	3.68	0.56
Stranger	3.13	0.98	2.92	1.02	3.03	0.72

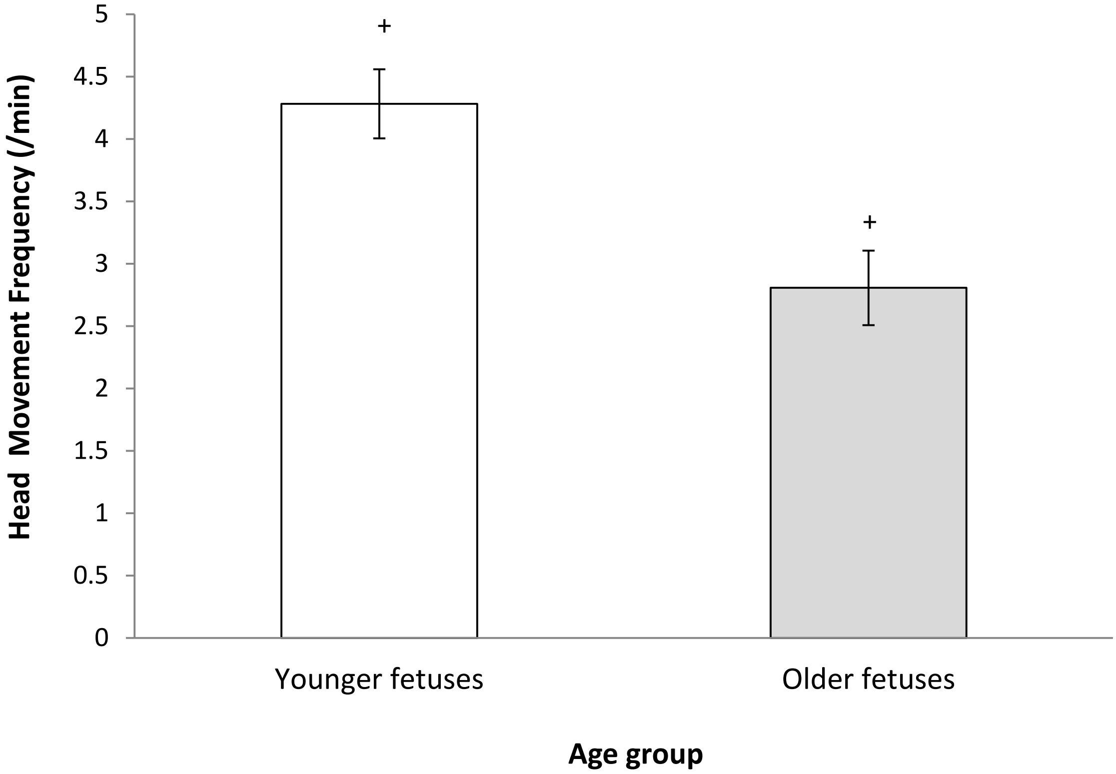

Figure 3.57. Average 'Head movement' frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

0-60s Interval analysis combined

Repeated-measures ANOVA Condition: 'Inactivity/Resting' Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in 'Inactivity/Resting' duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a tendency for a main effect of Condition *F* (3, 81) = 2.67, *p* = .053, η_p^2 = .09. Examination of the means suggests that fetuses altered 'Inactivity/Resting' duration between Conditions. Polynomial contrasts indicated, in support of this, a tendency for cubic trend, *F* (1, 27) = 3.34, *p* = .079, η_p^2 = .11. Overall, there is a decrease produced by the means from 'Control' (M = 3.97) to the 'Mother' (M = 1.87) followed by an increase to 'Father' (M = 4.02) and 'Stranger' (M = 4.77) producing the cubic trend.

Post-hoc pairwise comparison revealed a tendency between 'Mother' and 'Stranger' conditions, with a higher 'Inactivity/Resting' duration during stranger's touch (M = 4.77) compared to mother (M = 1.87, *p*= .071) implying that the fetus was more active when the mother touched compared to a stranger's touch (see Figure 2.58). No further differences were found. The means and standard errors can be examined in Table 3.45.

Table 3.45. Means and standard errors (SE) on the duration of fetuses 'Inactivity/Resting' across conditions.

	Control	Mother	Father	Stranger
Mean	3.97	1.87	4.02	4.77
SE	0.89	0.65	0.87	0.86

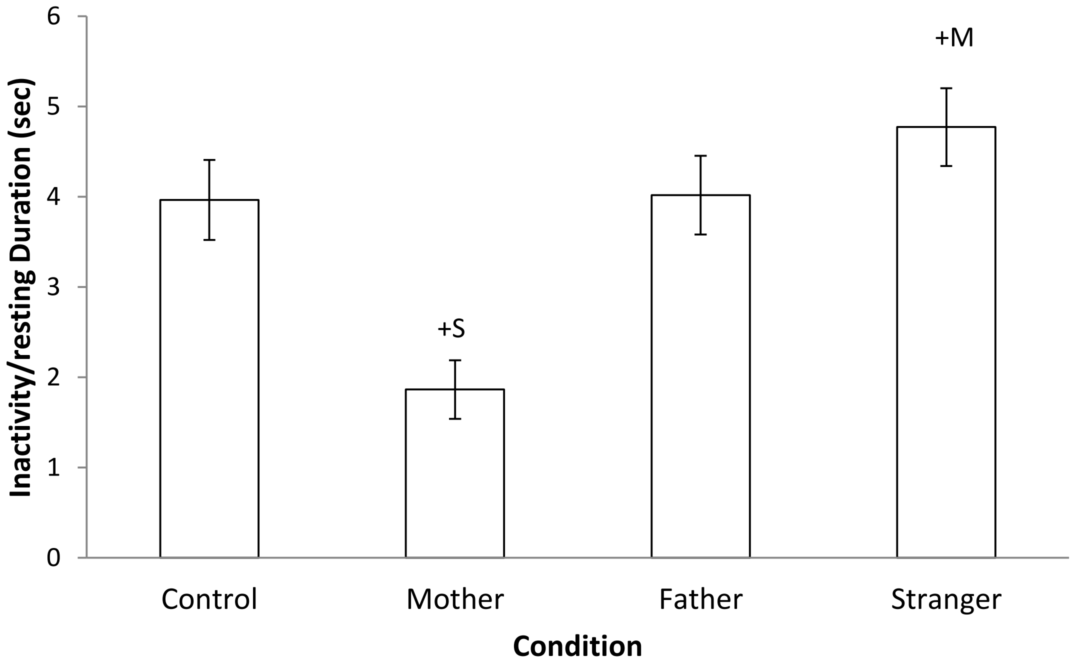

Figure 3.58. Average ‘Inactivity/Resting’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Self-touch’ Duration

A mixed ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Self-touch’. Results showed a tendency of main effect of Condition F (3, 78) = 2.19, p = .096, η_p^2 = .08, and a significant interaction between Condition and GA, F (3, 78) = 2.83, p = .044, η_p^2 = .10. No main effect of GA F (1, 26) = 0.17, p = .898, η_p^2 < .001, was found. In support of this polynomial contrasts of the main effect of Condition show a significant quadratic trend F (1, 26) = 4.78, p = .038, η_p^2 = .16. Overall, there is a decrease produced by the means from ‘Control’ (M = 8.47) to the ‘Mother’ (M = 6.18) followed by an increase to ‘Father’ (M = 7.35) and ‘Stranger’ (M = 7.94) producing the cubic trend. Polynomial contrasts of the interaction show a significant linear trend of Condition and GA F (1, 26) = 6.28, p = .019, η_p^2 = .19.

Post-hoc pairwise comparison of the main effect of Condition did not reveal any further effects (see Figure 3.59). Post-hoc pairwise comparison of the interaction between Condition and GA reveal a significant difference in

'Control' for younger and older fetuses, with older fetuses (M = 9.75) engaging in significantly longer 'Self-touch' compared to younger fetuses (M = 7.19, p = .033). A further significant difference can be observed in 'Stranger', with younger fetuses (M = 9.27) engaging in longer 'Self-touch' than older fetuses (M = 6.61, p = .034). A further significant difference can be seen for older fetuses, who engage in longer 'Self-touch' in 'Control' (M = 9.75) compared to 'Mother' (M = 5.87, p = .047). Lastly, a tendency was found for older fetuses in 'Control' compared to 'Stranger' with longer durations of 'Self-touch' in 'Control' (M = 9.75) compared to 'Stranger' (M = 6.61, p = .069) (see Figures 3.60 and 3.61). No further effects were found. The means and standard errors can be examined in Table 3.46.

Table 3.46. Means and standard errors (SE) of fetuses 'Self-touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.45	0.42	7.53	0.45		
Control	7.19	0.78	9.75	0.84	8.47	0.57
Mother	6.49	1.07	5.87	1.15	6.18	0.78
Father	6.83	0.89	7.87	0.95	7.35	0.65
Stranger	9.27	0.81	6.61	0.87	7.94	0.59

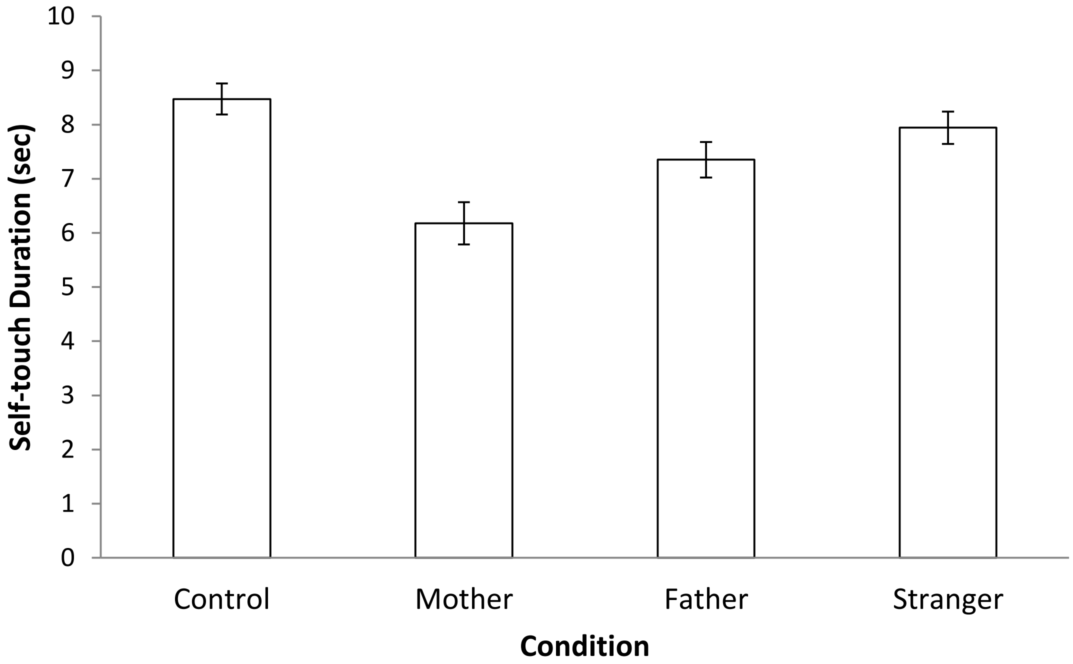

Figure 3.59. Average 'Self-touch' duration (in seconds) including standard errors for each condition.

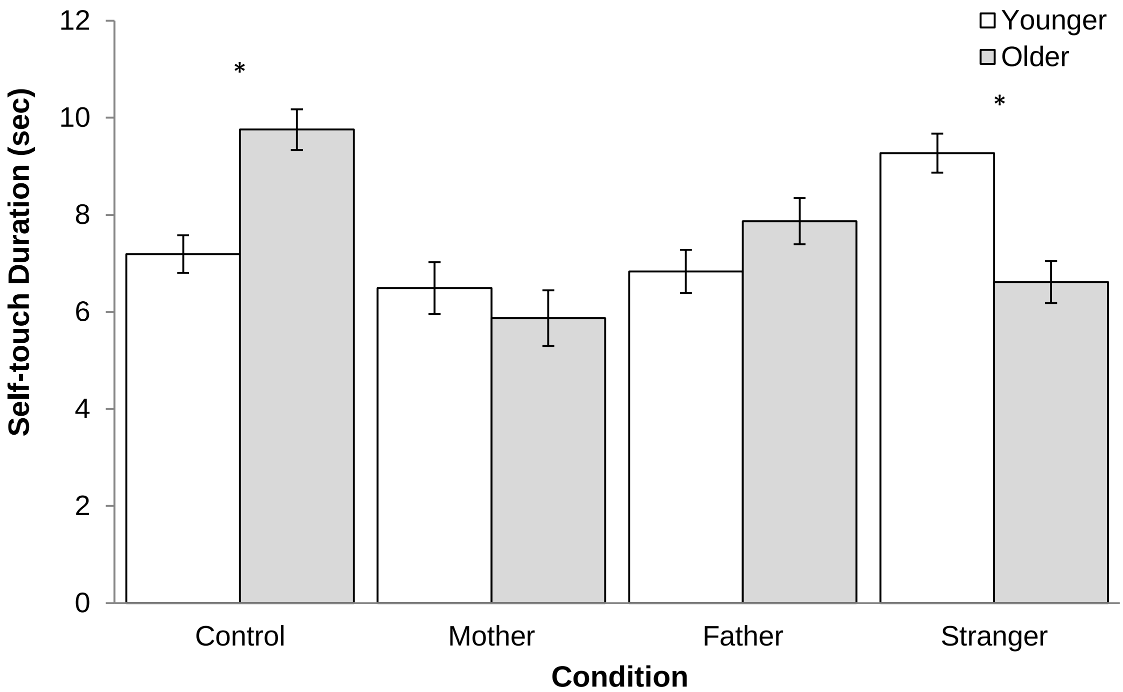

Figure 3.60. Average 'Self-touch' duration (in seconds) including standard errors for each condition (*<.05).

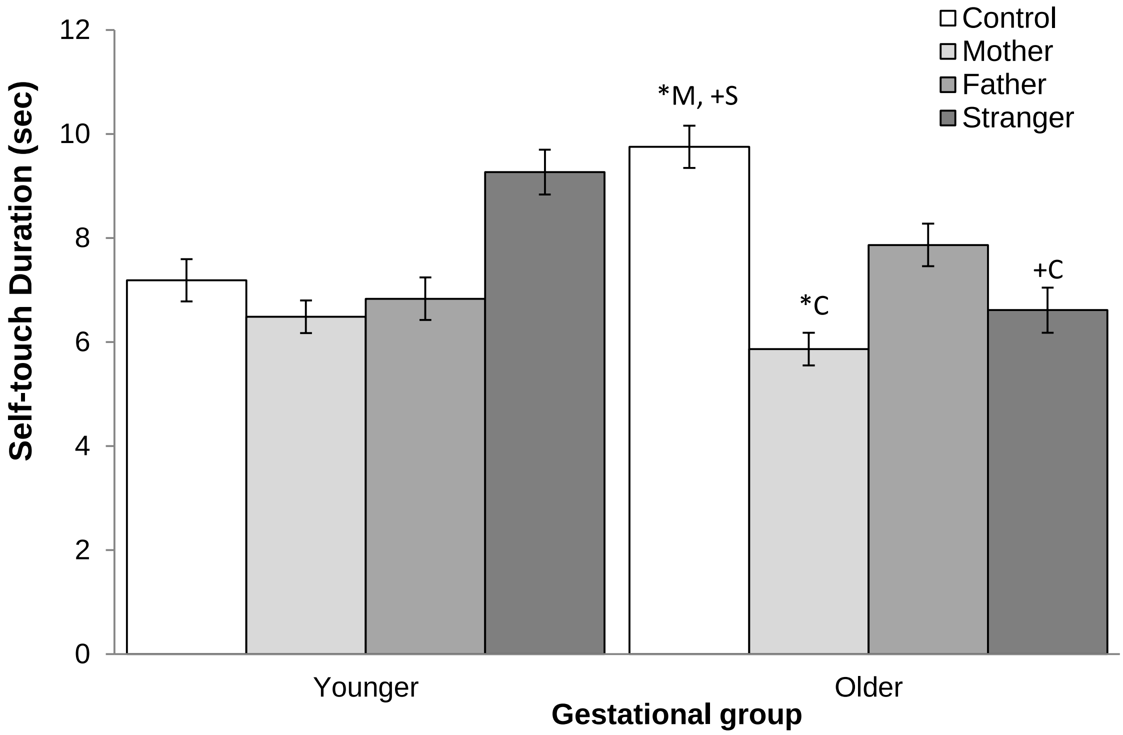

Figure 3.61. Average 'Self-touch' duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: 'External Touch' Frequency

A mixed ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of 'External touch'. Results showed no significant main effects of Condition F (3, 78) = 1.36, p = .262, η_p^2 = .05, or an interaction F (3, 78) = 0.77, p = .516, η_p^2 = .03. However, a significant main effect of GA, F (1, 26) = 4.38, p = .046, η_p^2 = .14, was revealed, showing that 'External touch' duration is dependent on GA.

Post-hoc pairwise comparison of the main effect of GA showed that younger fetuses (M = 1.45) display significantly more externally directed touch compared to older fetuses (M = 0.79, p = .046) (see Figure 3.62). No further effects were found. The means and standard errors can be examined in Table 3.47.

Table 3.47. Means and standard errors (SE) of fetuses ‘External touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.45	0.22	0.79	0.23		
Control	1.40	0.30	0.39	0.32	0.89	0.22
Mother	1.53	0.41	1.31	0.44	1.42	0.30
Father	1.73	0.35	0.77	0.37	1.25	0.26
Stranger	1.13	0.29	0.69	0.31	0.91	0.21

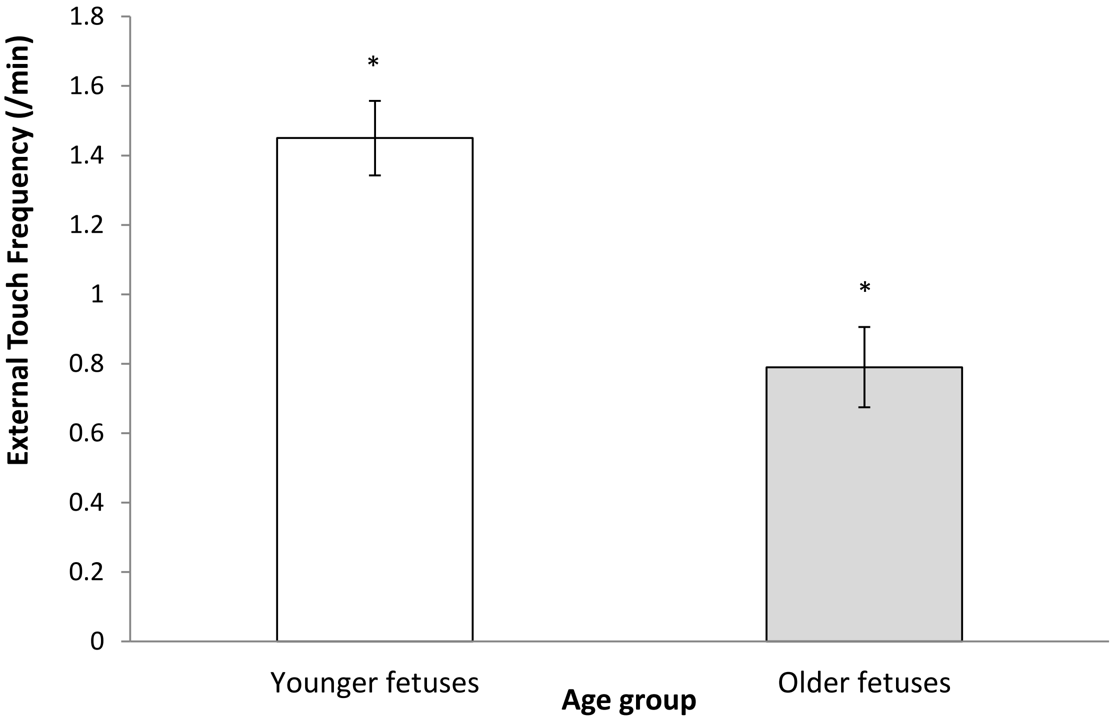

Figure 3.62. Average ‘External touch’ frequency (per minute) including standard errors for GA (younger and older fetuses) (*< .05).

Mixed-design ANOVA Condition*GA: ‘External Touch’ Duration

A mixed ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘External touch’. Results showed no main effect of Condition F (3, 78) = 1.73, p = .167, η_p^2 = .06, or main effect of GA F (1, 26) = 0.58, p = .453, η_p^2 = .02. Results revealed a marginally significant interaction between Condition and GA, F (3, 78) = 2.20, p = .095, η_p^2 = .08. In support of this polynomial contrasts of the interaction show a significant linear trend of Condition and GA F (1, 26) = 6.70, p = .095, η_p^2 = .08.

Post-hoc pairwise comparisons of the interaction between Condition and GA show a significant difference in ‘Control’ for younger and older fetuses, with younger fetuses (M = 6.10) engaging in significantly longer ‘External touch’ compared to older fetuses (M = 0.87, p = .007). A further marginally significant difference can be observed for older fetuses engaging in longer durations of ‘External touch’ in ‘Father’ (M = 6.03) compared to control (M = 0.87, p = .070). Older fetuses also tend to engage longer in ‘External touch’ in ‘Stranger’ (M = 5.32) compared to ‘Control’ (M = 0.86, p = .085) (see Figure 3.63 and 3.64). No further effects were found. The means and standard errors can be examined in Table 3.48.

Table 3.48. Means and standard errors (SE) of fetuses 'External touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	5.64	1.06	4.46	1.13		
Control	6.10	1.23	0.87	1.32	3.49	0.90
Mother	6.10	1.76	5.61	1.89	5.85	1.29
Father	6.54	1.59	6.03	1.70	6.29	1.16
Stranger	3.80	1.60	5.32	1.71	4.56	1.17

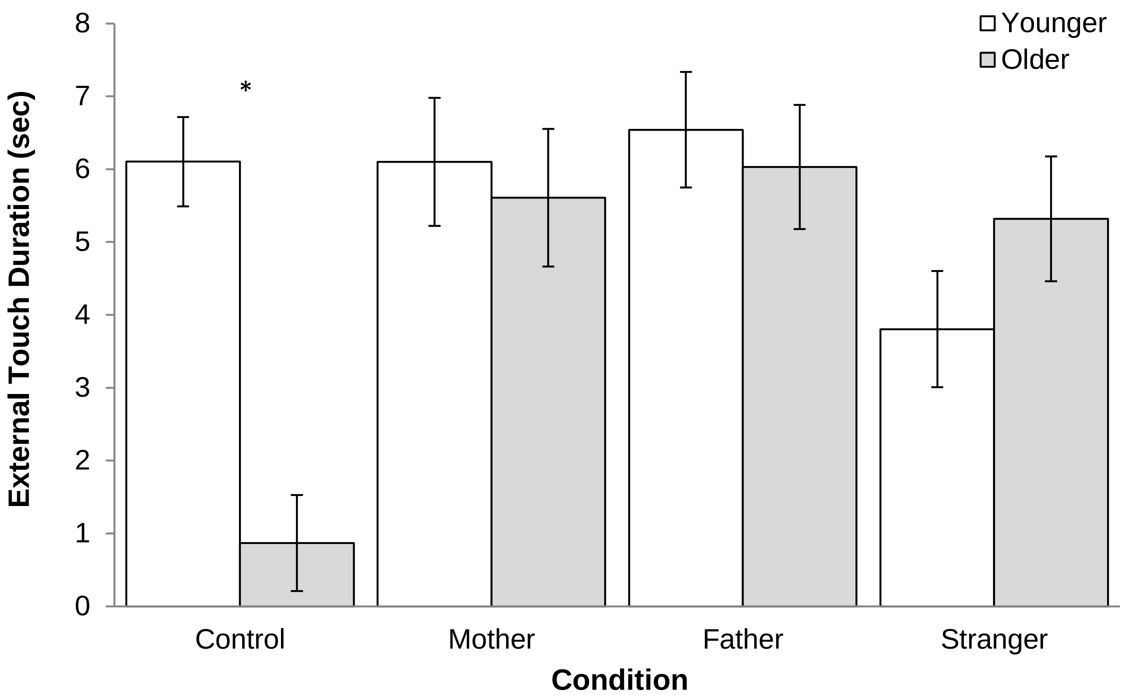

Figure 3.63. Average 'External touch' duration (in seconds) including standard errors for each condition (*<.05).

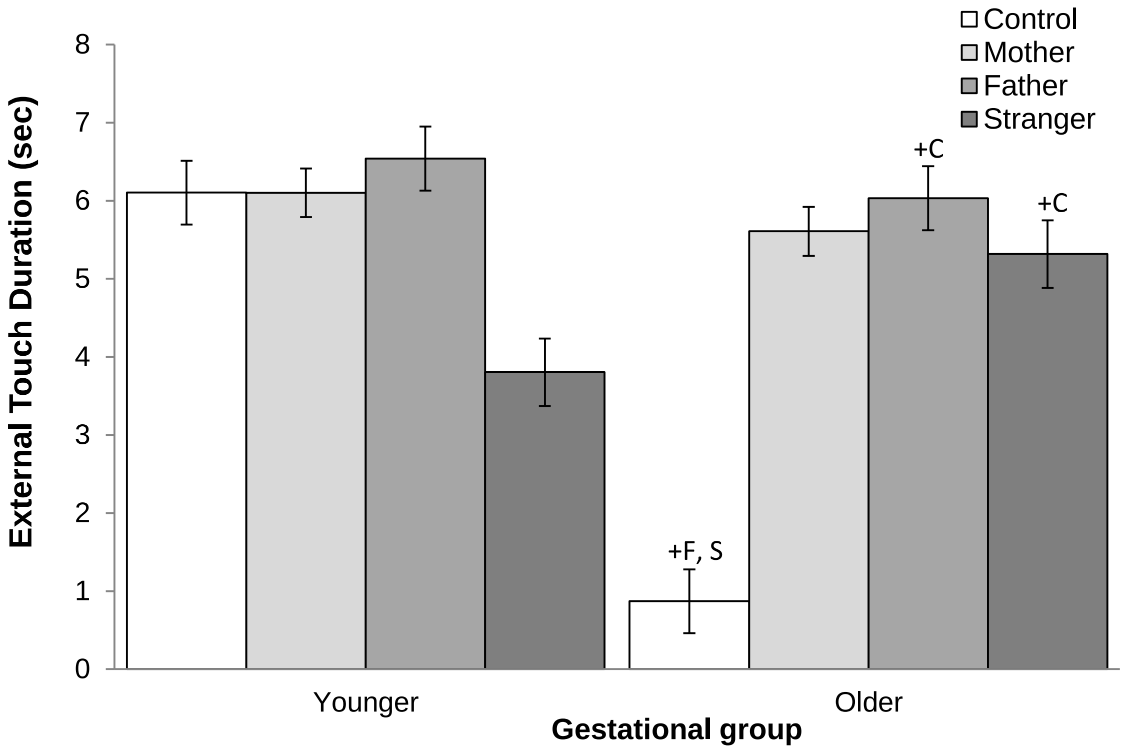

Figure 3.64. Average ‘External touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Inactivity/Resting’ Duration

A mixed ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Inactivity/Resting’. The main effect of Condition indicates a significant difference, F (3, 78) = 3.01, p = .035, η_p^2 = .10. Neither a main effect of GA F (1, 26) = 2.88, p = .102, η_p^2 = .10, nor an interaction effect F (3, 78) = 1.92, p = .133, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a tendency for a quadratic trend F (1, 26) = 3.04, p = .093, η_p^2 = .11, and a cubic trend F (1, 26) = 3.24, p = .084, η_p^2 = .11, of Condition, indicating a decrease from ‘Control’ (M = 4.06) to ‘Mother’ (M = 1.85), followed by an increase to ‘Father’ (M = 4.03) and ‘Stranger’ (M = 4.91).

Post-hoc pairwise comparison of the Condition main effect showed a significant difference between ‘Mother’ and ‘Stranger’ with a higher duration of ‘Inactivity/Resting’ in ‘Stanger’ (M = 4.03) compared to ‘Mother’ (M = 1.85. p =

.032) (see Figure 3.65). No further effects were found. The means and standard errors can be examined in Table 3.49.

Table 3.49. Means and standard errors (SE) of fetuses 'Inactivity/Resting' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.91	0.64	4.51	0.69		
Control	2.72	1.18	5.41	1.27	4.06	0.87
Mother	2.08	0.90	1.62	0.97	1.85	0.66
Father	3.92	1.21	4.13	1.30	4.03	0.89
Stranger	2.92	1.07	6.91	1.15	4.91	0.79

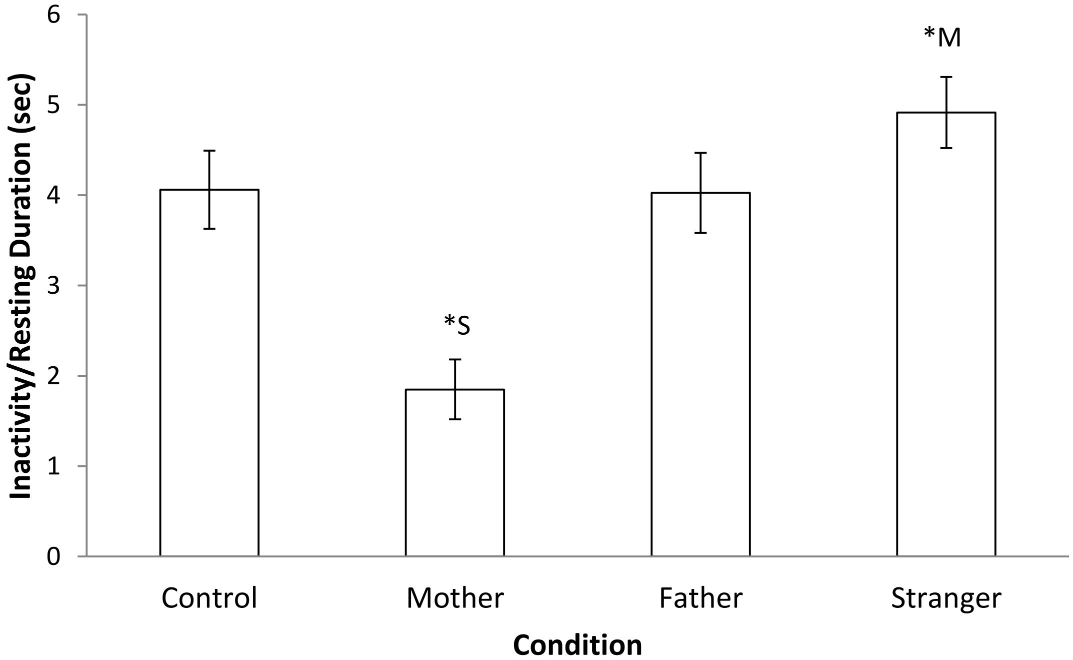

Figure 3.65. Average 'Inactivity/Resting' duration (in seconds) including standard errors for each condition ((*<.05).

30-60s Interval

Repeated-measures ANOVA Condition*GA: 'Head movement' Frequency

A repeated-measures ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of 'Head movement'. Results showed a tendency between Conditions F (3, 81) = 2.59, p = .059, η_p^2 = .09. Examination of means suggests that fetuses 'Head movement' frequency tends to differ between the Conditions. Polynomial contrasts indicated, in support of this, that there was a significant cubic trend, F (1, 27) = 5.53, p = .026, η_p^2 = .17. Overall, there is an increase produced by the means from 'Control' (M = 3.36) to 'Mother' (M = 5.43) followed by a decrease to 'Father' (M = 2.93) and another increase to the 'Stranger' condition (M = 3.00) producing the cubic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.66). The means and standard errors can be examined in Table 3.50.

Table 3.50. Means and standard errors (SE) on the frequency of fetuses 'Head movements' across conditions.

	Control	Mother	Father	Stranger
Mean	3.36	5.43	2.93	3.00
SE	0.77	1.00	0.66	0.75

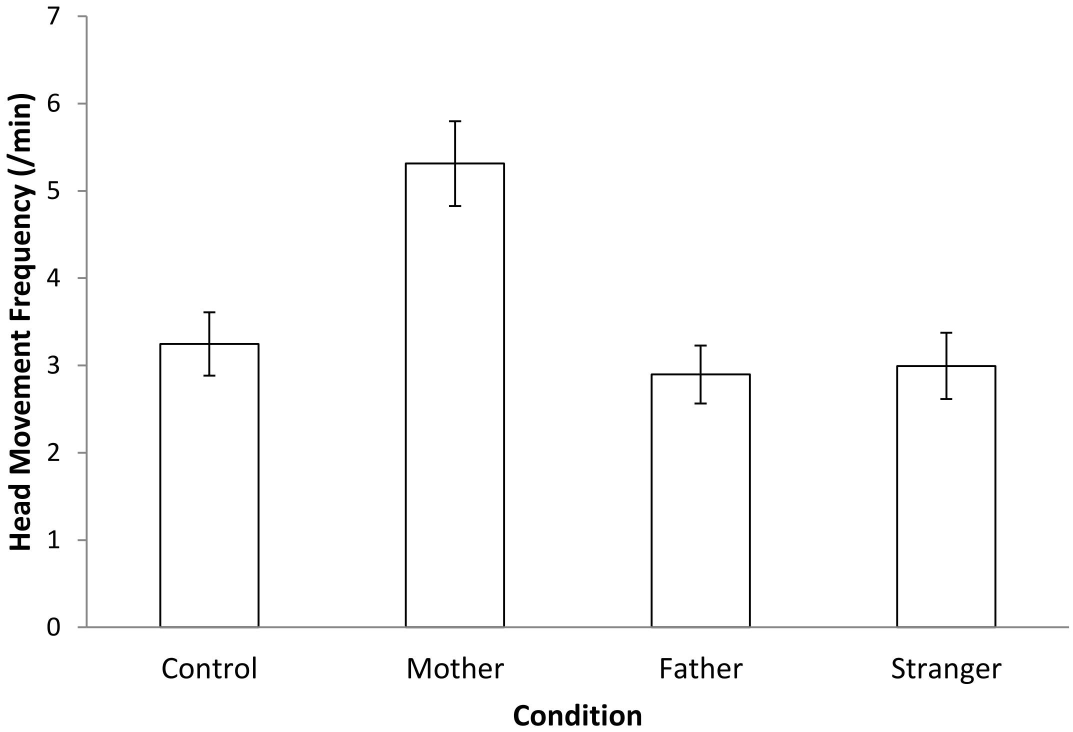

Figure 3.66. Average ‘Head movement’ frequency (per minute) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: ‘Uterus touch’ Duration

A mixed ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Uterus touch’. Results showed a tendency for an interaction between Condition and GA, F (3, 78) = 2.53, p = .063, η_p^2 = .09. No main effects of Condition F (3, 78) = 2.12, p = .104, η_p^2 = .08, or GA F (1, 26) = 0.00, p = .987, η_p^2 < .001, were found. In support of the interaction, polynomial contrasts indicated a significant linear trend F (1, 26) = 5.550, p = .026, η_p^2 = .18, of Condition and GA.

Post-hoc pairwise comparison of the interaction showed that younger fetuses touch the uterus significantly more in ‘Control’ (M = 26.57) compared to older fetuses (M = 0.32, p = .027). In the ‘Stranger’ condition older fetuses tend to respond longer (M = 23.85) compared to younger fetuses (M = 2.51, p = .071). Older fetuses touch the uterus significantly longer in the ‘Mother’ (M = 37.42) compared to ‘Control’ (M = 0.32, p = .037) condition (see Figures 3.67

and 3.68). No further effects were found. The means and standard errors can be examined in Table 3.51.

Table 3.51. Means and standard errors (SE) of fetuses ‘Uterus touch’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	19.07	4.93	19.20	5.30		
Control	26.57	7.65	0.32	8.22	13.44	5.61
Mother	28.28	11.19	37.42	12.02	32.85	8.21
Father	18.94	9.03	15.21	9.70	17.08	6.63
Stranger	2.51	7.73	23.85	8.31	13.81	5.67

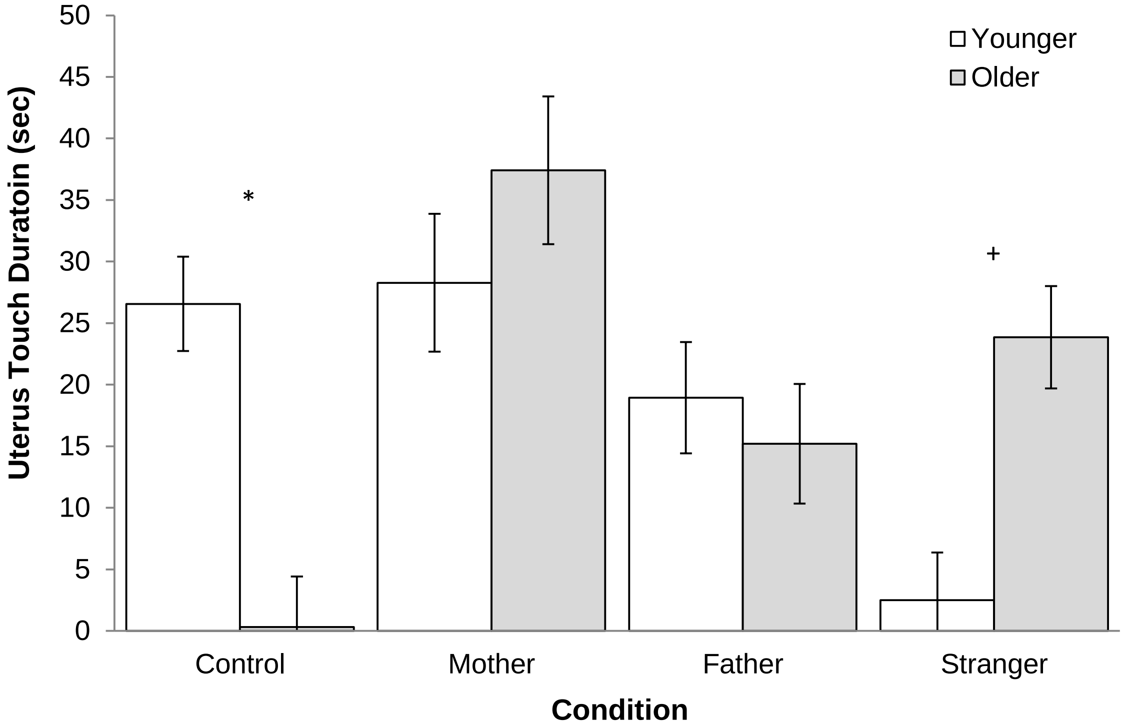

Figure 3.67. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions across gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *<.05).

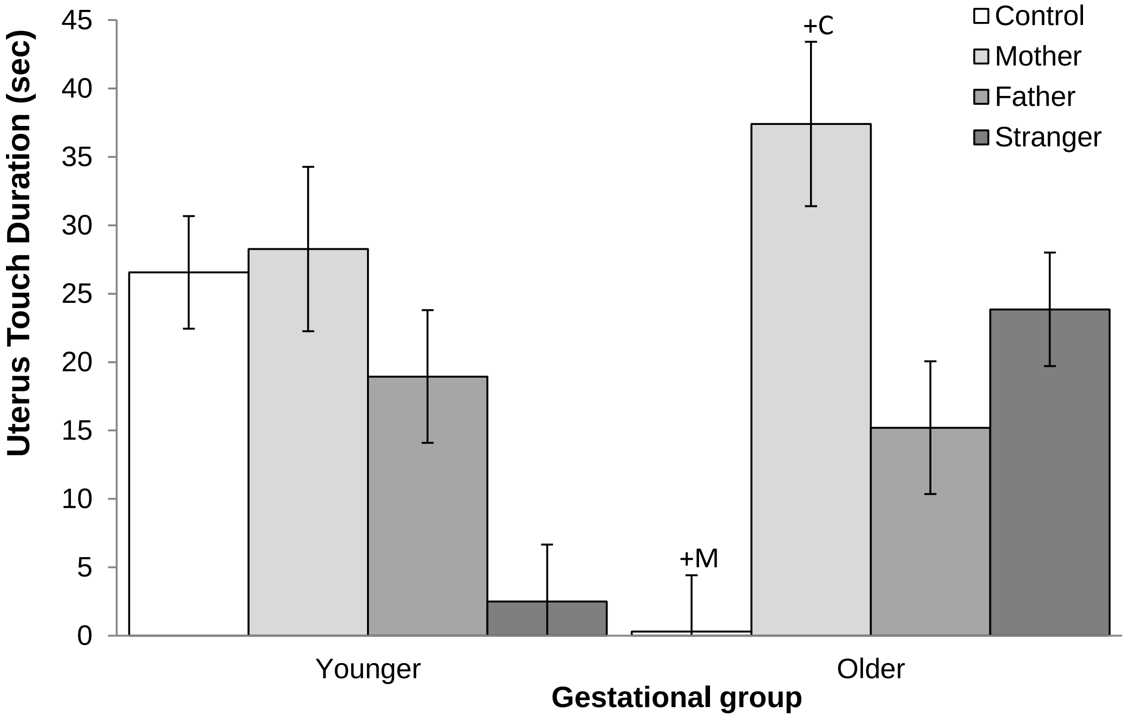

Figure 3.68. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Arms-crossed' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Arms-crossed' behaviours. Results indicate a tendency of main effect of GA, F (1, 26) = 3.30, p = .081, η_p^2 = .11, and interaction between Condition and GA F (3, 78) = 2.33, p = .080, η_p^2 = .08. No main effect of Condition F (3, 78) = 1.61 p = .195, η_p^2 = .06, was found. This indicates that 'Arms-crossed' duration tends to differ between age groups and tends to be dependent on Condition and GA. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 4.07, p = .054, η_p^2 = .14, of Condition and GA.

Post-hoc pairwise comparison of the main effect of GA showed a tendency for older fetuses (M = 26.50) displaying longer 'Arms-crossed' compared to younger fetuses (M = 11.47, p = .081) (see Figure 3.69).

Post-hoc pairwise comparison of the interaction revealed that older fetuses (M = 45.68) displayed significantly longer 'Arms-crossed' in 'Stranger' compared to younger fetuses (M = 6.61, p = .010). Older fetuses display significantly more 'Arms-crossed' in 'Stranger' (M = 45.68) compared to 'Mother' (M = 5.53, p = .011) (see Figures 3.70 and 3.71). No further effects were found. The means and standard errors can be examined in Table 3.52.

Table 3.52. Means and standard errors (SE) of fetuses 'Arms-crossed' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	11.47	5.64	26.50	6.06		
Control	11.96	9.80	31.67	10.52	21.37	7.33
Mother	8.74	6.16	8.35	6.61	7.96	4.60
Father	11.72	9.02	23.56	9.69	20.48	7.52
Stranger	7.53	9.54	44.63	10.25	26.14	7.04

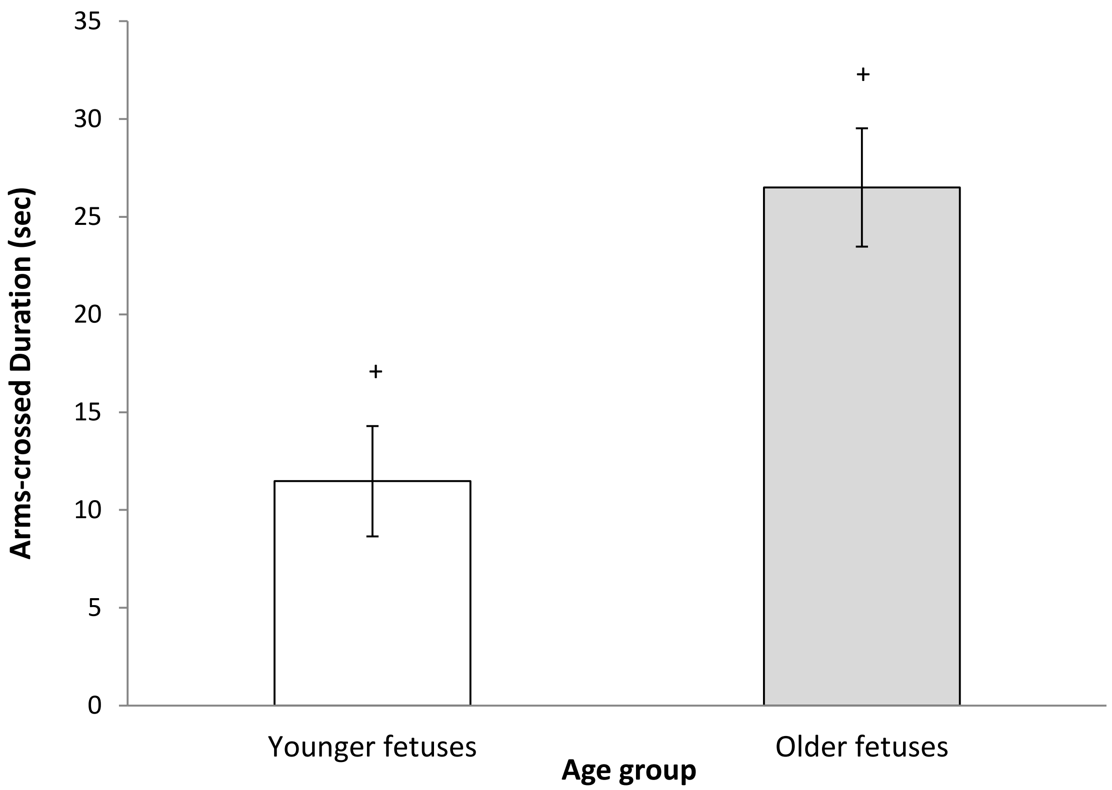

Figure 3.69. Average 'Arms-crossed' duration (in seconds) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

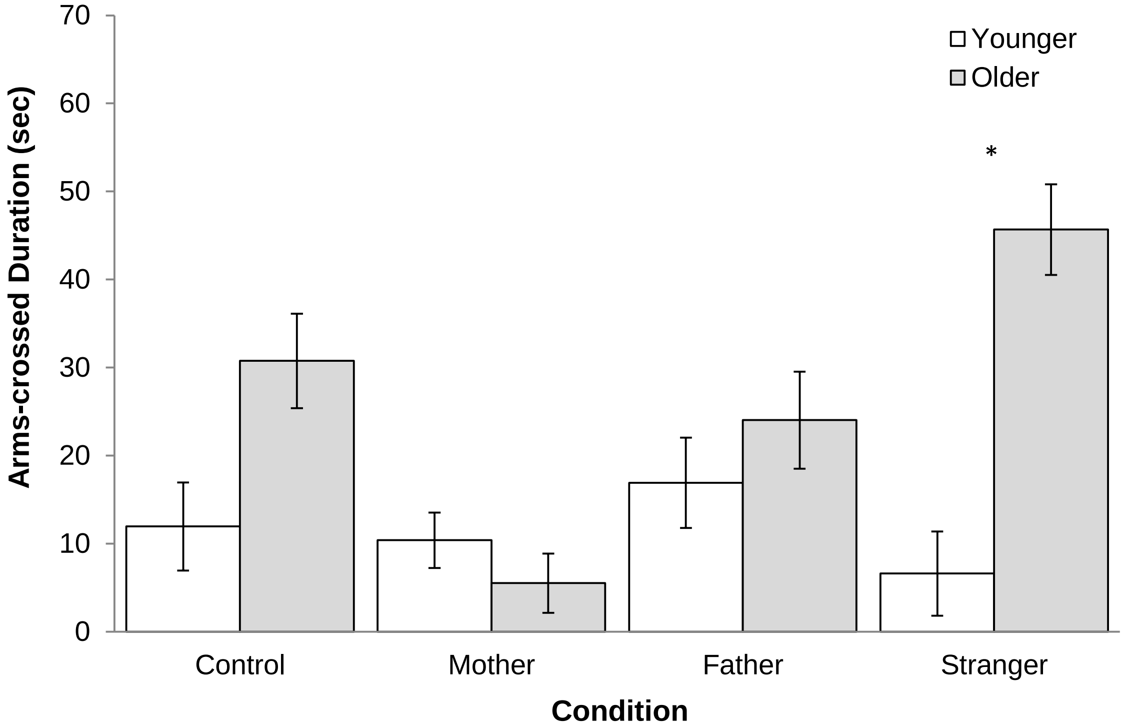

Figure 3.70. Average ’Arms-crossed’ duration (in seconds) including standard errors for all four conditions across gestational ages (younger and older fetuses) (*<.05).

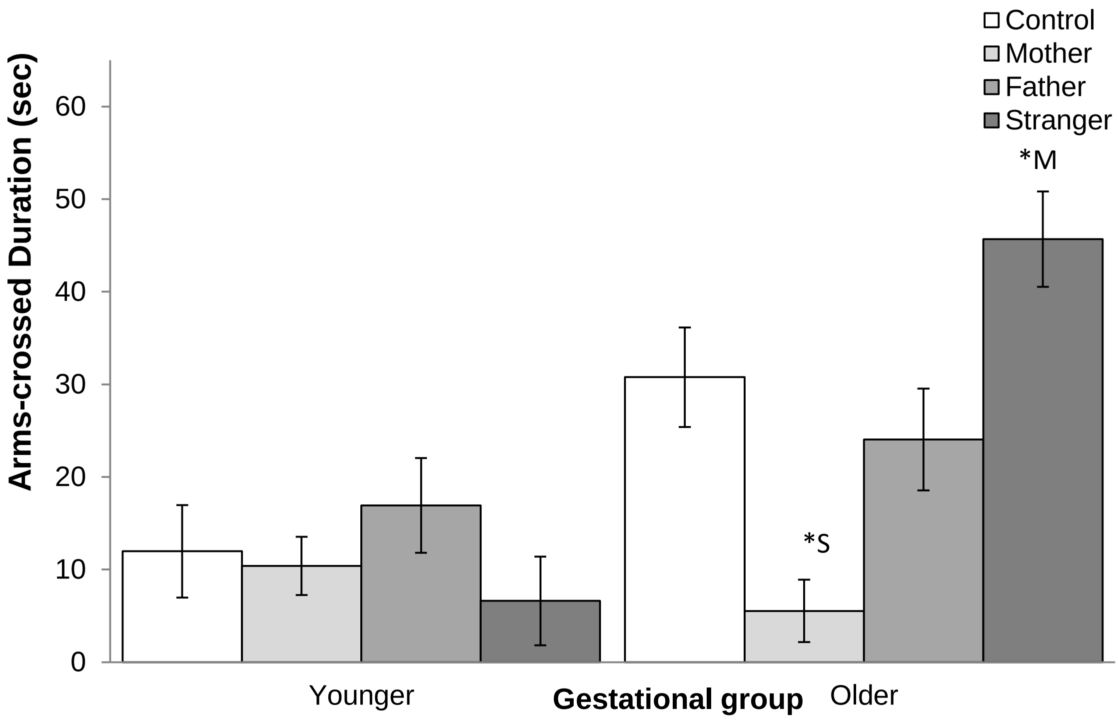

Figure 3.71. Average ‘Arms-crossed’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*<.05).

Mixed-design ANOVA Condition*GA: 'Head movement' Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of 'Head movement'. The Condition main effect indicates a trend, F (3, 78) = 2.42, p = .072, η_p^2 = .09. There was a tendency of main effect of GA F (1, 26) = 3.88, p = .059, η_p^2 = .13, and no interaction of Condition and GA F (3, 78) = 1.14, p = .338, η_p^2 = .04, were found. In support of the tendencies in the main effects, polynomial contrasts indicated a significant cubic trend F (1, 26) = 5.17, p = .032, η_p^2 = .32, of Condition. Overall, an increase of the means from 'Control' (M = 3.25), to 'Mother' (M = 5.31) followed by a decrease in the 'Father' condition (M = 2.90). However, the 'Stranger' condition has a somewhat higher mean (M = 3.00) producing the cubic trend.

Post-hoc pairwise comparison of the main effect of Condition does not reveal any further effects (see Figure 3.72).

Post-hoc pairwise comparison of the main effect of GA indicates a tendency for increased 'Head movement's for younger fetuses (M = 4.53) compared to older fetuses (M = 2.69, p = .059) (see Figure 3.73). No further effects were found. The means and standard errors can be examined in Table 3.53.

Table 3.53. Means and standard errors (SE) of fetuses 'Head movement' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	4.53	0.64	2.69	0.68		
Control	4.80	0.99	1.69	1.06	3.25	0.73
Mother	6.93	1.33	3.69	1.42	5.31	0.97
Father	3.33	0.90	2.46	0.97	2.90	0.66
Stranger	3.07	1.04	2.92	1.12	3.00	0.76

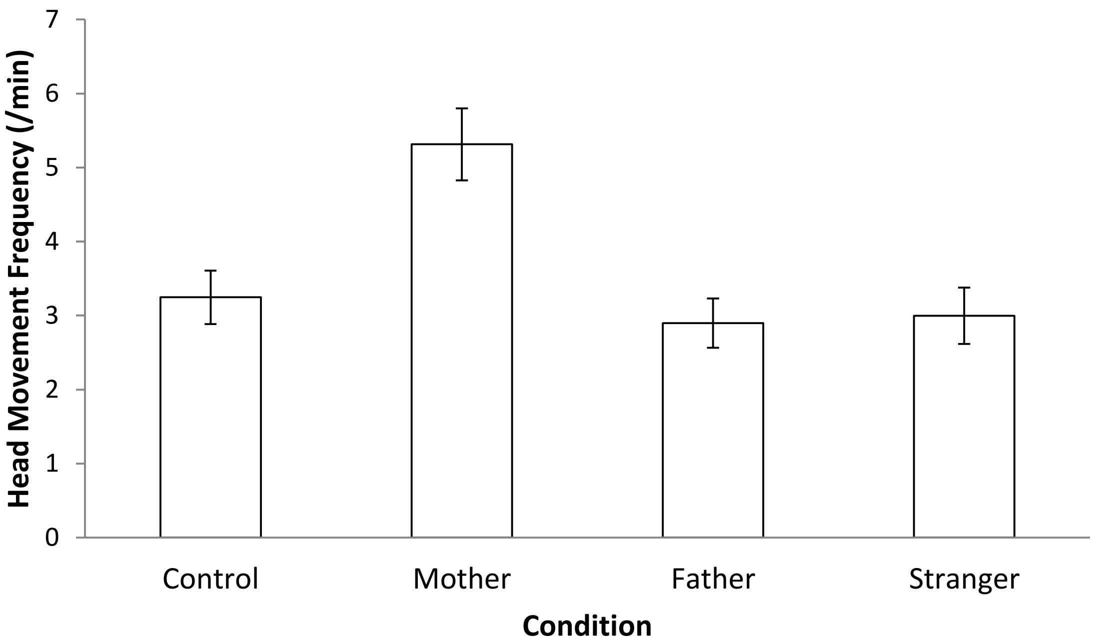

Figure 3.72. Average 'Head movement' frequency (per minute) including standard errors for each condition.

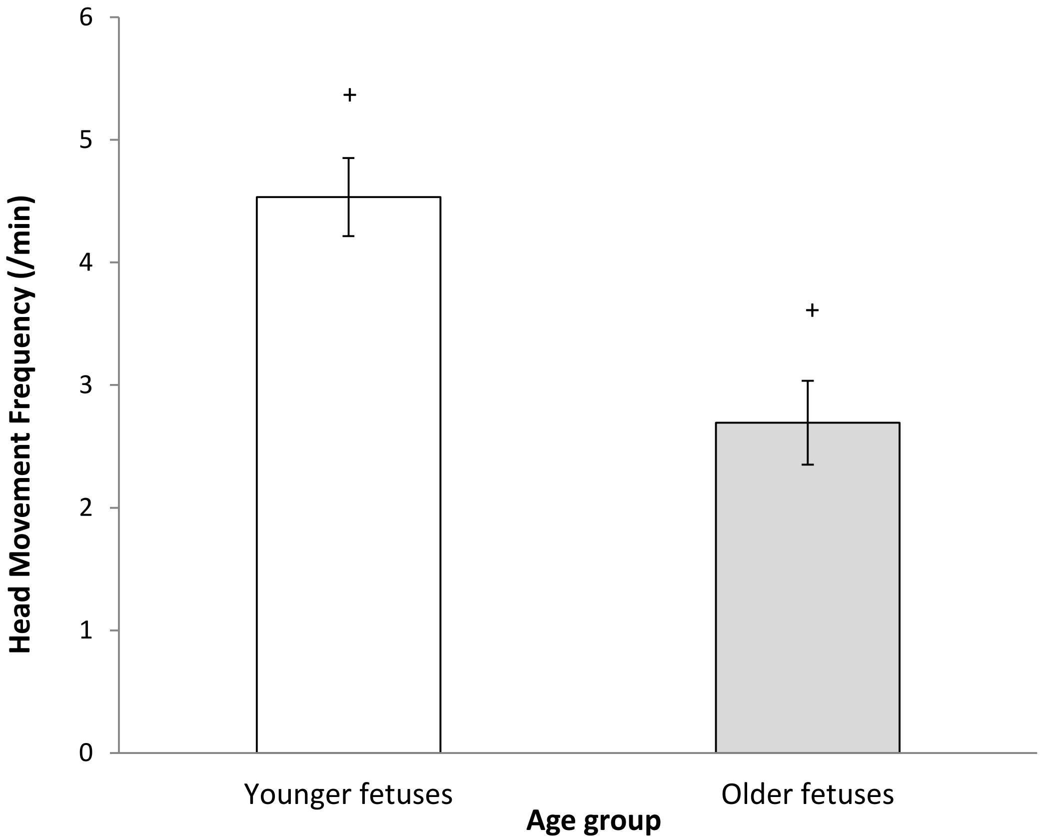

Figure 3.73. Average 'Head movement' frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

30-60s Interval analysis combined

Repeated-measures ANOVA Condition: 'Self-touch' Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in 'Self-touch' duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (3, 81) = 2.78, p = .047, η_p^2 = .09. Examination of the means suggests that fetuses altered 'Self-touch' duration between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 9.12, p = .005, η_p^2 = .25. Overall, there is a decrease produced by the means from 'Control' (M = 8.54), to 'Mother' (M = 5.89), followed by an increase to 'Father' (M = 7.17), and 'Stranger' (M = 8.32) producing the quadratic trend.

Post-hoc pairwise comparison revealed a tendency between ‘Mother’ and ‘Control’ conditions, with longer ‘Self-touch’ duration during ‘Control’ (M = 8.54) compared to ‘Mother’ (M = 5.89, *p* = .056) implying that the fetus touched the own body more during ‘Control’ compared to ‘Mother’ (see Figure 3.74). No further effects were found. The means and standard errors can be examined in Table 3.54.

Table 3.54. Means and standard errors (SE) on the duration of fetuses ‘Self-touch’ across conditions.

	Control	Mother	Father	Stranger
Mean	8.54	5.89	7.17	8.32
SE	0.60	0.84	0.76	0.67

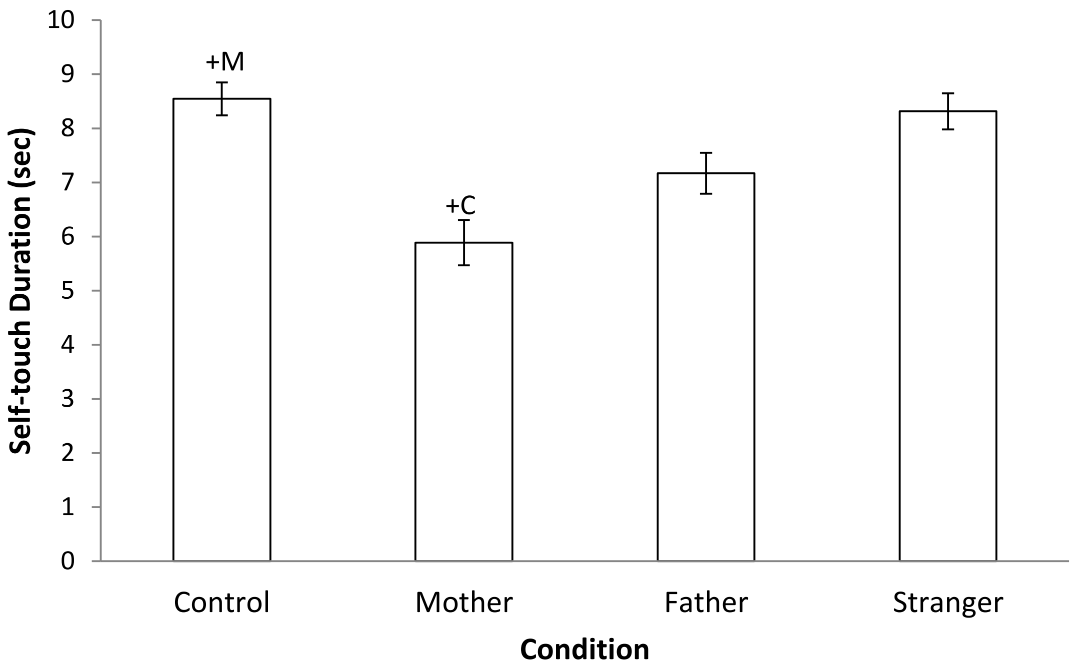

Figure 3.74. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: ‘Inactivity/Resting’ Frequency

A repeated-measures ANOVA, using Greenhouse-Geisser correction, was conducted to assess whether there are differences in ‘Inactivity/Resting’ frequency between the four Conditions (Control, Mother, Father, Stranger). Results showed a tendency for a main effect of Condition F (1.95, 52.55) = 2.84, p = .069, η_p^2 = .10. Examination of the means suggests that fetuses altered ‘Inactivity/Resting’ frequency between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 4.31, p = .048, η_p^2 = .14. Overall, there is a decrease produced by the means from ‘Control’ (M = 1.21), to ‘Mother’ (M = 0.57), followed by an increase to ‘Father’ (M = 1.21), and ‘Stranger’ (M = 1.79) producing the quadratic trend.

Post-hoc pairwise comparison revealed a tendency between ‘Mother’ and ‘Stranger’ conditions, with a tendency for a higher ‘Inactivity/Resting’ frequency during stranger’s touch (M = 1.79) compared to ‘Mother’ implying that the fetus was more active when the mother touched compared to a stranger’s touch (M = 0.57, p = .062) (see Figure 3.75). No other effects were found. The means and standard errors can be examined in Table 3.55.

Table 3.55. Means and standard errors (SE) on the frequency of fetuses ‘Inactivity/Resting’ across conditions.

	Control	Mother	Father	Stranger
Mean	1.21	0.57	1.21	1.79
SE	0.31	0.17	0.21	0.46

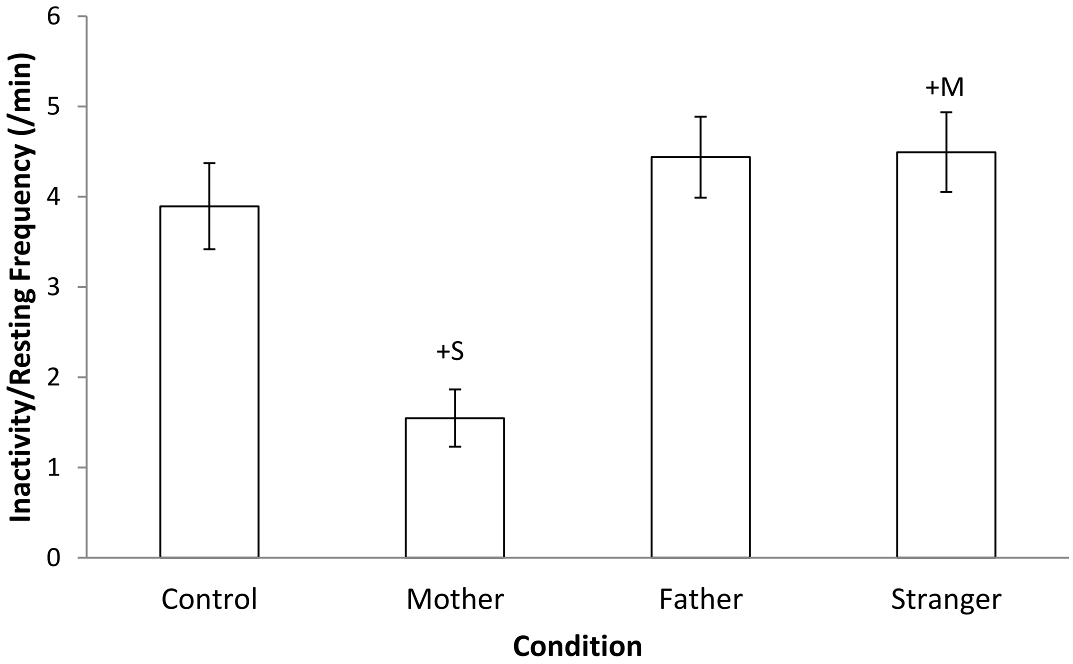

Figure 3.75. Average ‘Inactivity/Resting’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: ‘Inactivity/Resting’ Duration

A repeated-measures ANOVA, was conducted to assess whether there are differences in ‘Inactivity/Resting’ duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (3, 81) = 3.29, p = .025, η_p^2 = .11. Examination of the means suggests that fetuses altered ‘Inactivity/Resting’ duration between Conditions. Polynomial contrasts indicated, in support of this, a significant cubic trend, F (1, 27) = 6.25, p = .018, η_p^2 = .19, and a tendency for a linear trend F (1, 27) = 3.17, p = .086, η_p^2 = .11. Overall, there is a decrease produced by the means from ‘Control’ (M = 3.90), to ‘Mother’ (M = 1.55), followed by an increase to ‘Father’ (M = 4.44), and ‘Stranger’ (M = 4.50) producing the linear and quadratic trends.

Post-hoc pairwise comparison revealed a significant difference between ‘Mother’ (M = 1.55) and ‘Father’ conditions (M = 4.44, p = .043), with a longer ‘Inactivity/Resting’ duration during father’s touch compared to ‘Mother’ implying that the fetus was more active when the mother touched compared to the father. A tendency can be observed between ‘Mother’ and ‘Stranger’, with longer durations of ‘Inactivity/Resting’ during ‘Mother’ (M = 1.55) compared to ‘Stranger’ (M = 4.50, p = .060) (see Figure 3.76). No further effects were found. The means and standard errors can be examined in Table 3.56.

Table 3.56. Means and standard errors (SE) on the duration of fetuses ‘Inactivity/Resting’ across conditions.

	Control	Mother	Father	Stranger
Mean	1.21	0.57	1.21	1.79
SE	0.31	0.17	0.21	0.46

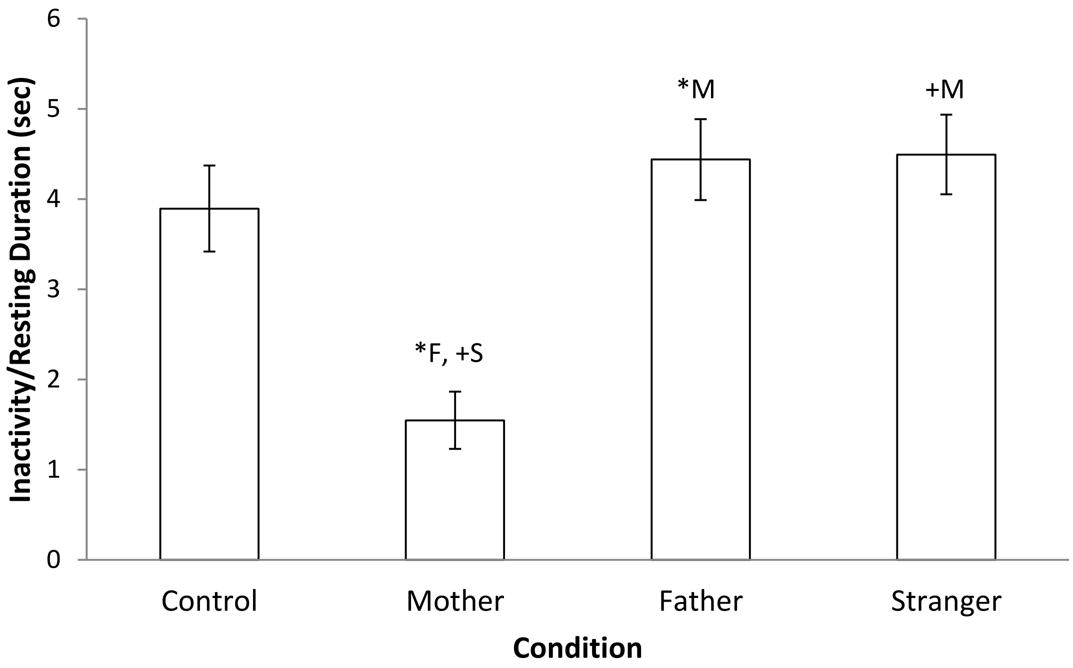

Figure 3.76. Average ‘Inactivity/Resting’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: ‘Self-touch’ Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Self-touch’. Results showed a significant of main effect of Condition F (3, 78) = 3.01, p = .035, η_p^2 = .10, and a marginally significant interaction between Condition and

GA, F (3, 78) = 2.43, p = .072, η_p^2 = .09. No main effect of GA F (1, 26) = 0.13, p = .718, η_p^2 = .01, was found. In support of this polynomial contrasts of the main effect of Condition show a significant quadratic trend F (1, 26) = 8.911, p = .006, η_p^2 = .20, Overall, there is a decrease produced by the means from 'Control' (M = 8.64) to the 'Mother' (M = 5.86) followed by an increase to 'Father' (M = 7.17) and 'Stranger' (M = 8.22) producing the quadratic trend. Polynomial contrasts of the interaction show a significant linear trend of Condition and GA F (1, 26) = 6.27, p = .018, η_p^2 = .20.

Post-hoc pairwise comparison of the main effect of Condition, using Bonferroni corrections, revealed a significant difference between 'Control' and 'Mother', with longer 'Self-touch' durations during 'Control' (M = 8.64) compared to 'Mother' (M = 5.86, p = .029) (see Figure 3.77).

Post-hoc pairwise comparison of the interaction between Condition and GA reveal a significant difference in 'Control' for younger and older fetuses, with older fetuses (M = 9.95) engaging in significantly longer 'Self-touch' compared to younger fetuses (M = 7.32, p = .027). A further significant difference can be observed in 'Stranger', with younger fetuses (M = 9.58) engaging in longer 'Self-touch' than older fetuses (M = 6.86, p = .040). A further significant difference can be seen for older fetuses, who engage in longer 'Self-touch' in 'Control' (M = 9.95) compared to 'Mother' (M = 5.39, p = .012). Lastly, a tendency was found for older fetuses in 'Control' compared to 'Stranger' with longer durations of 'Self-touch' in 'Control' (M = 9.95) compared to 'Stranger' (M = 6.86, p = .095) (see Figures 3.78 and 3.79). No further effects were found. The means and standard errors can be examined in Table 3.57.

Table 3.57. Means and standard errors (SE) of fetuses 'Self-touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.60	0.48	7.34	0.51		
Control	7.32	0.76	9.95	0.82	8.64	0.56
Mother	6.32	1.16	5.39	1.25	5.86	0.85
Father	7.18	1.05	7.17	1.13	7.17	0.77
Stranger	9.58	0.86	6.86	0.92	8.22	0.63

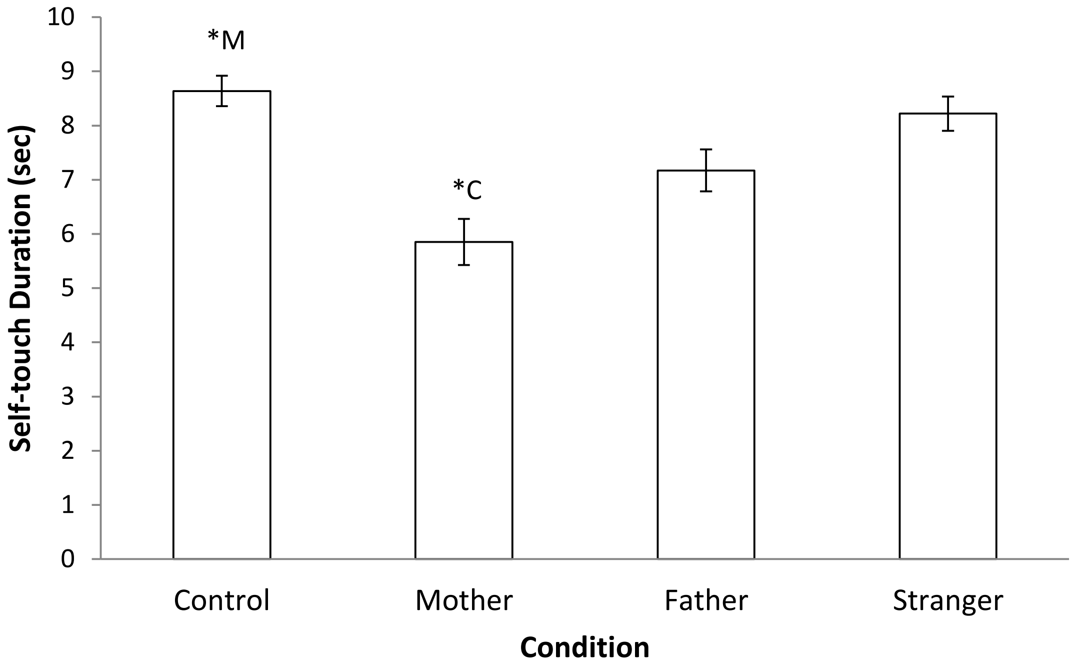

Figure 3.77. Average 'Self-touch' duration (in seconds) including standard errors for each condition (*< .05).

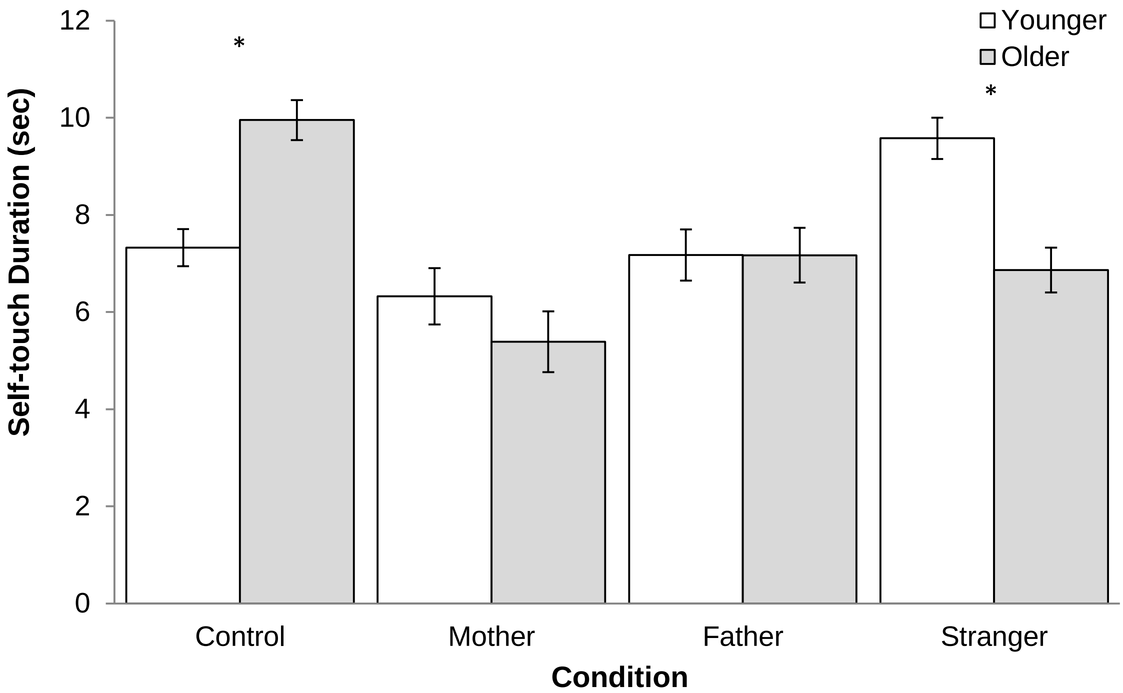

Figure 3.78. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (*<.05).

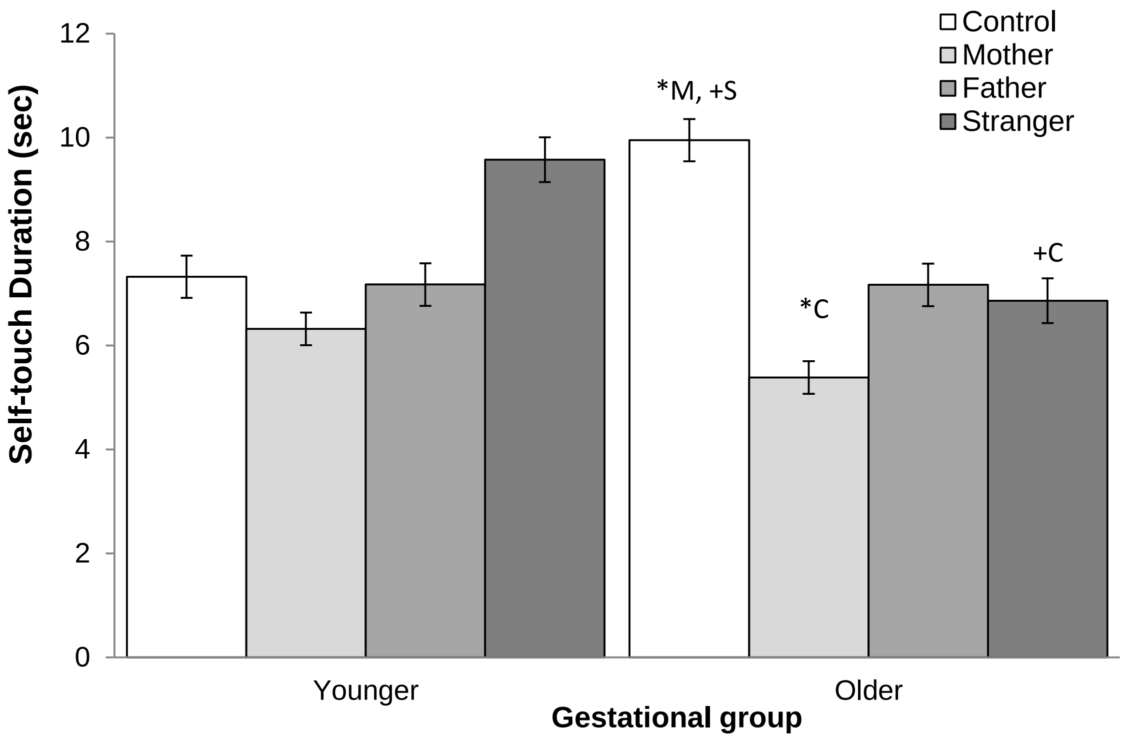

Figure 3.79. Average ‘Self-touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: ‘External Touch’ Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘External touch’. Results showed no significant main effects of Condition *F* (3, 78) = 1.20, *p* = .316, η_p^2 = .04, or an interaction *F* (3, 78) = 0.91, *p* = .439, η_p^2 = .03. However, a tendency for a main effect of GA, *F* (1, 26) = 3.05, *p* = .092, η_p^2 = .11, was revealed, showing that ‘External touch’ duration tends to be dependent on GA.

Post-hoc pairwise comparison of the main effect of GA showed that younger fetuses (M = 2.10) had a tendency to display more externally directed touch compared to older fetuses (M = 1.19, *p* = .092) (see Figure 3.80). No further effects were found. The means and standard errors can be examined in Table 3.58.

Table 3.58. Means and standard errors (SE) of fetuses ‘External touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.10	0.35	1.19	0.38		
Control	2.13	0.41	0.31	0.44	1.22	0.30
Mother	2.27	0.54	1.85	0.58	2.06	0.40
Father	2.27	0.56	1.39	0.60	1.83	0.41
Stranger	1.73	0.60	1.23	0.64	1.48	0.44

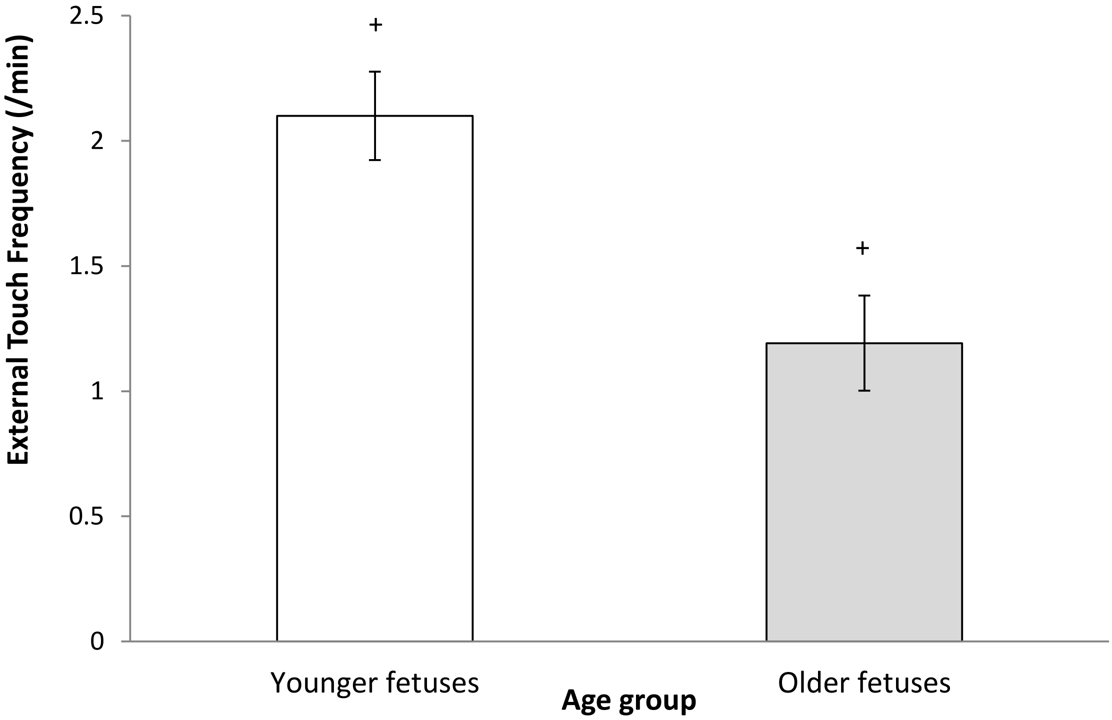

Figure 3.80. Average ‘External touch’ frequency (per minute) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Inactivity/Resting’ Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Inactivity/Resting’. The main effect of Condition indicates a marginally significant difference, F (3, 78) = 2.80, p = .072, η_p^2 = .10. Neither a main effect of GA F (1, 26) = 0.00, p = .984, $\eta_p^2 < .001$, nor an interaction effect F (3, 78) = 0.21, p = .892, η_p^2 = .01, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 4.44, p = .045, η_p^2 = .15, of Condition, indicating a decrease from ‘Control’ (M = 1.23) to ‘Mother’ (M = 0.56), followed by an increase to ‘Father’ (M = 1.21), and ‘Stranger’ (M = 1.79).

Post-hoc pairwise comparison of the Condition main effect showed a marginally significant difference between ‘Mother’ and ‘Stranger’ with a higher frequency of ‘Inactivity/Resting’ in ‘Stanger’ (M = 1.79) compared to ‘Mother’ (M = 0.56, p = .067) (see Figure 3.81). No further effects were found. The means and standard errors can be examined in Table 3.59.

Table 3.59. Means and standard errors (SE) of fetuses 'Inactivity/Resting' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.20	0.25	1.19	0.27		
Control	1.07	0.44	1.39	0.47	1.23	0.32
Mother	0.67	0.24	0.46	0.26	0.56	0.18
Father	1.33	0.30	1.08	0.32	1.21	0.22
Stranger	1.73	0.65	1.85	0.69	1.79	0.47

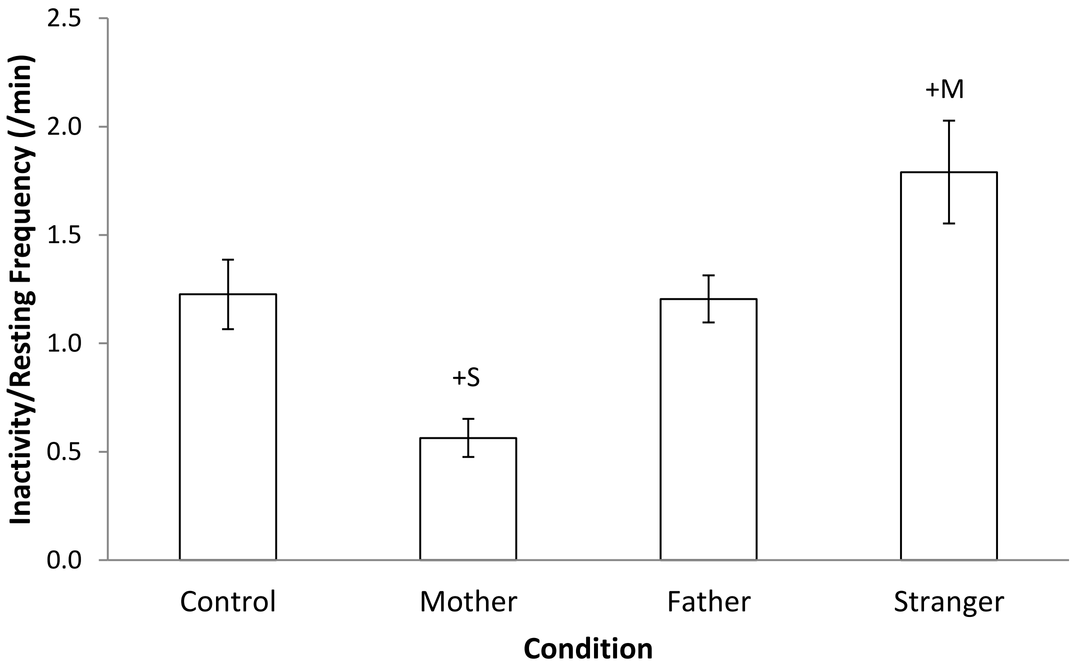

Figure 3.81. Average 'Inactivity/Resting' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Inactivity/Resting' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Inactivity/Resting'. The main effect of Condition indicates a significant difference, F (3, 78) = 3.60, p = .017, η_p^2 = .12. Neither a main effect of GA F (1, 26) = 2.09, p = .160, η_p^2 = .08, nor an interaction effect F (3, 78) = 1.91, p = .135, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 6.06, p = .021, η_p^2 = .19, and a tendency for a linear trend of Condition F (1, 26) = 3.35, p = .079, η_p^2 = .11, indicating a decrease from 'Control' (M = 3.99) to 'Mother' (M = 1.53), followed by an increase to 'Father' (M = 4.44) and 'Stranger' (M = 4.64).

Post-hoc pairwise comparison of the Condition main effect showed a significant difference between 'Mother' and 'Stranger' with a longer duration of 'Inactivity/Resting' in 'Stanger' (M = 4.64) compared to 'Mother' (M = 1.53, p = .028). A further tendency can be seen between 'Mother' and 'Father', with a longer duration of 'Inactivity/Resting' during 'Father' (M = 4.44) compared to 'Mother' (M = 1.54, p = .052) (see Figure 3.82). No further effects were found. The means and standard errors can be examined in Table 3.60.

Table 3.60. Means and standard errors (SE) of fetuses 'Inactivity/Resting' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.89	0.71	4.40	0.77		
Control	2.72	1.28	5.25	1.38	3.99	0.94
Mother	1.73	0.89	1.34	0.95	1.53	0.65
Father	4.47	1.25	4.41	1.34	4.44	0.92
Stranger	2.66	1.11	6.62	1.19	4.64	0.81

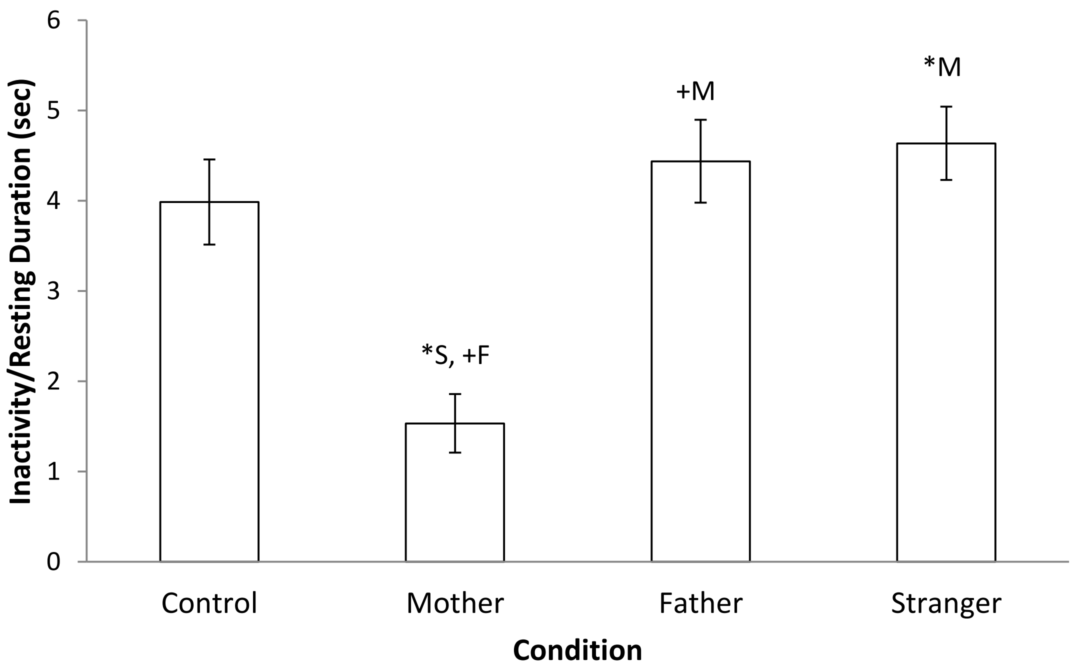

Figure 3.82. Average 'Inactivity/Resting' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

60-90s Interval

Repeated-measures ANOVA Condition: 'Arm movement' Frequency

A repeated-measures ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequency of 'Arm movements'. Results showed a tendency for a main effect of Condition F (3, 81) = 2.51, p = .064, η_p^2 = .09. Examination of the means suggests that fetuses tend to move their arms differently between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 5.88, p = .022, η_p^2 = .18. Overall, there is an increase produced by the means from 'Control' (M = 4.93), to 'Mother' (M = 3.00), 'Father' (M = 3.00), and 'Stranger' (M = 5.21), producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.83). The means and standard errors can be examined in Table 3.61.

Table 3.61. Means and standard errors (SE) on the frequency of fetuses 'Arm movements' across conditions.

	Control	Mother	Father	Stranger
Mean	4.93	3.00	3.00	5.21
SE	0.75	0.80	0.80	0.96

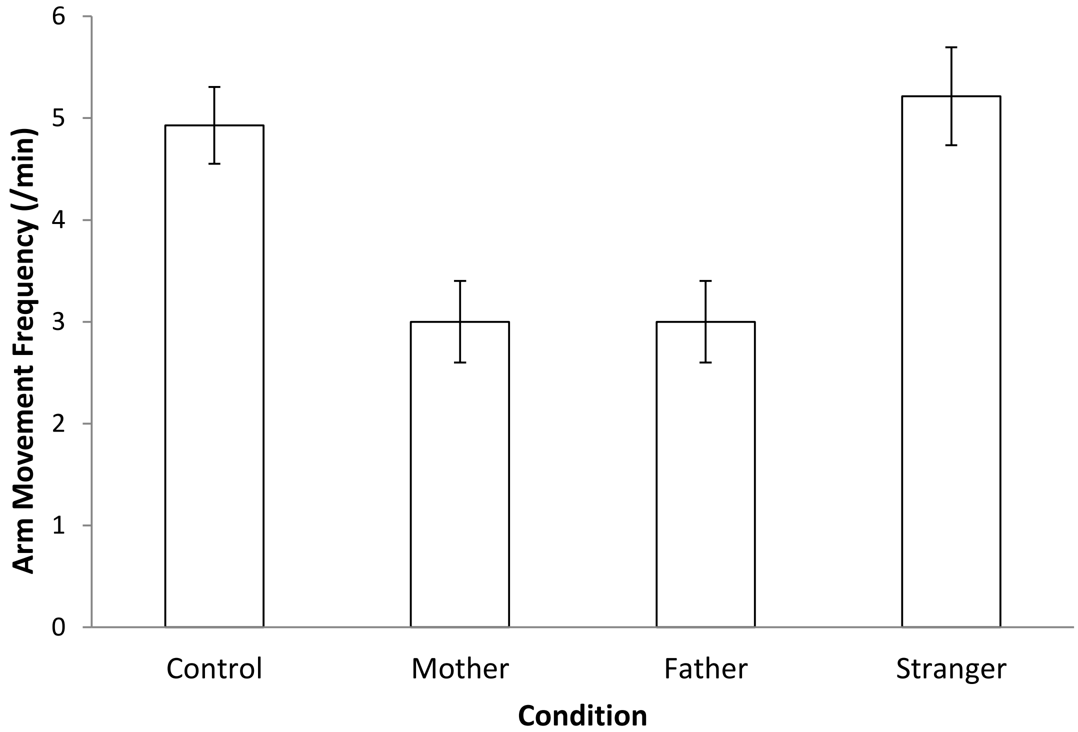

Figure 3.83. Average ‘Arm movement’ frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: ‘Mouth movement’ Frequency

A repeated-measures ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of. Results showed a significant main effect of Condition F (3, 81) = 4.48, p = .006, η_p^2 = .14. Polynomial contrasts indicated, in support of this, a significant linear trend, F (1, 27) = 4.31, p = .047, η_p^2 = .14, quadratic trend F (1, 27) = 4.66, p = .040, η_p^2 = .15, and cubic trend F (1, 27) = 4.31, p = .047, η_p^2 = .14. Overall, there is a decrease in the means from ‘Control’ (M = 1.00) to ‘Mother’ (M = 0.71) and ‘Father’ (M = 0.71) while the ‘Stranger’ condition has a somewhat higher mean (M = 2.29) producing the cubic and quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.84). The means and standard errors can be examined in Table 3.62.

Table 3.62. Means and standard errors (SE) on the frequency of fetuses 'Mouth movement' across conditions.

	Control	Mother	Father	Stranger
Mean	1.00	0.71	0.71	2.29
SE	0.44	0.58	0.58	0.69

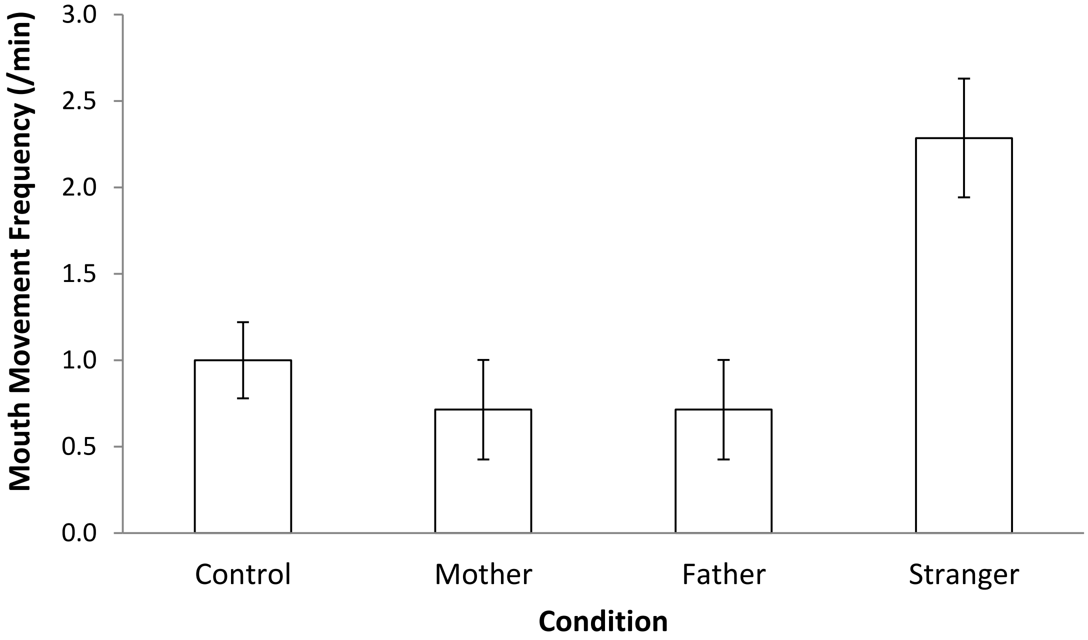

Figure 3.84. Average 'Mouth movement' frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: 'Face press' Frequency

A repeated-measures ANOVA, using Greenhouse-Geisser correction, was conducted to assess whether there are differences in frequency of the 'Face press' between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (1.83, 49.46) = 4.24, p = .023, η_p^2 = .14. Examination of means suggests that fetuses 'Face press' frequency differed significantly between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant quadratic trend, F (1, 27) = 6.53, p = .017, η_p^2 = .20. Overall, there is an increase produced by the means from 'Control' (M = 0.50) over 'Mother' (M = 1.00) and 'Father' (M = 2.00) conditions. However, the ‘Stranger’ condition has a somewhat lower mean (M = 0.57) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.85). The means and standard errors can be examined in Table 3.63.

Table 3.63. Means and standard errors (SE) on the frequency of fetuses ‘Face press’ against the uterus across conditions.

	Control	Mother	Father	Stranger
Mean	0.50	1.00	1.00	0.57
SE	0.17	0.22	0.22	0.17

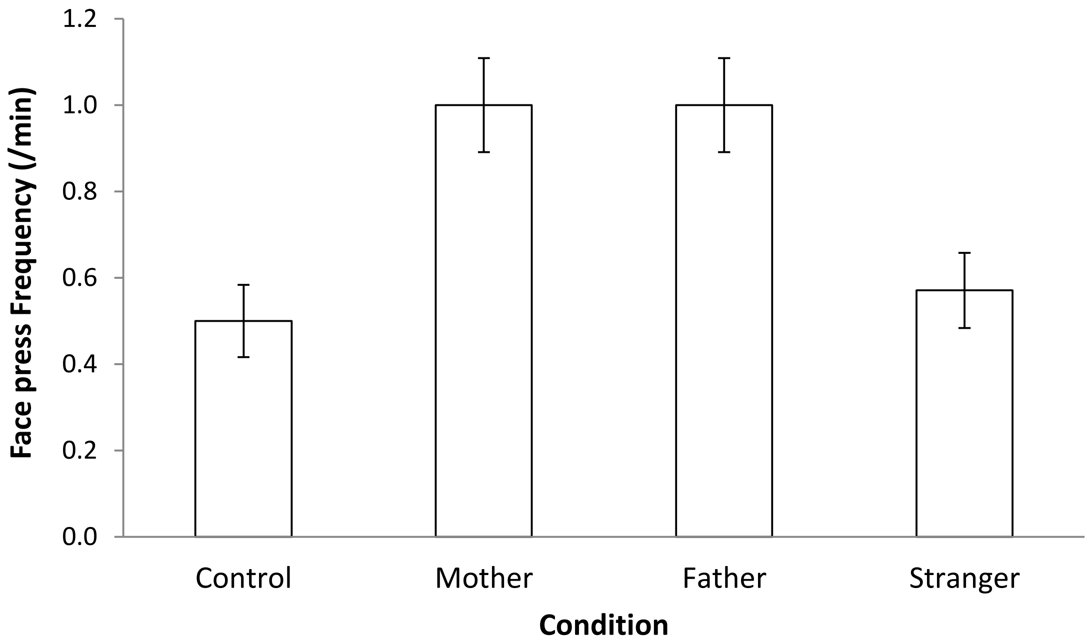

Figure 3.85. Average ‘Face press’ frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: ‘Face press’ Duration

A repeated-measures ANOVA, using Greenhouse-Geisser correction, was conducted to assess whether there are differences in duration of the ‘Face press' between the four Conditions (Control, Mother, Father, Stranger). Results indicate that there was a significant main effect of Condition F (1.94, 52.31) = 4.00, p = .025, η_p^2 = .13. Examination of these means suggests that the 'Face press' duration differed significantly between Conditions. Polynomial contrasts indicated, in support of this, that there was a significant quadratic trend, F (1, 27) = 6.60, p = .016, η_p^2 = .20. Overall, there is an increase produced by the means from 'Control' (M = 22.78), over 'Mother' (M = 45.69), and 'Father' (M = 45.69) conditions. However, the 'Stranger' condition has a somewhat lower mean (M = 28.57) than producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.86). The means and standard errors can be examined in Table 3.64.

Table 3.64. Means and standard errors (SE) on the duration of fetuses 'Face press' against the uterus across conditions.

	Control	Mother	Father	Stranger
Mean	22.78	45.69	45.69	28.57
SE	7.72	9.47	9.47	8.69

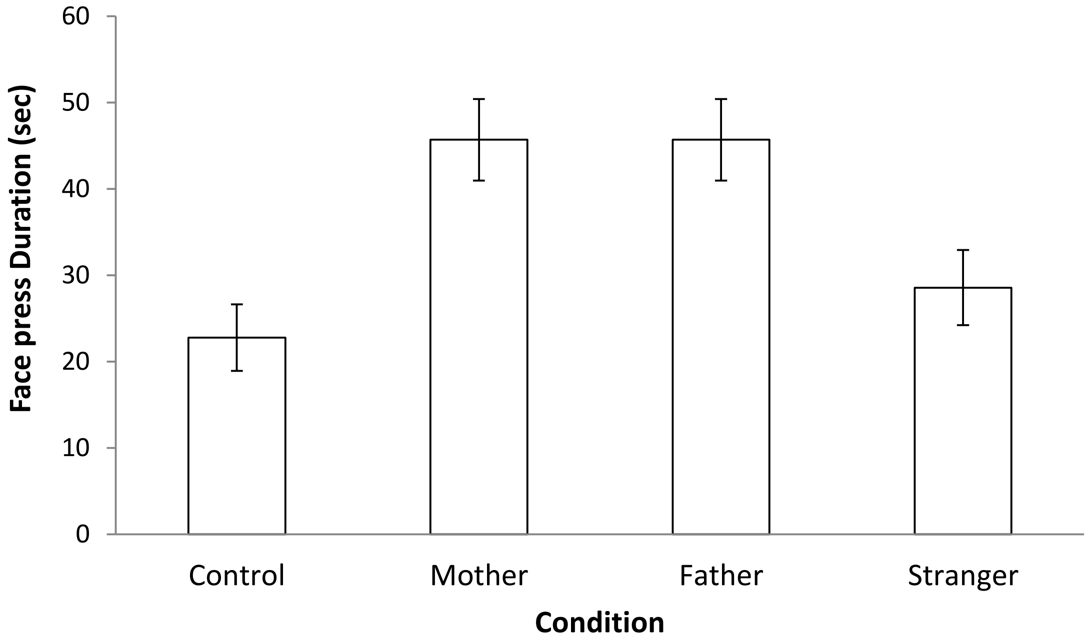

Figure 3.86. Average ‘Face press’ duration (in seconds) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: ‘Arm movement’ Frequency

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Arm movements’. The main effect of Condition indicates a trend, F (1.95, 50.76) = 2.25, p = .091, η_p^2 = .09. No significant main effect of GA F (1, 26) = 1.81, p = .191, η_p^2 = .07, or an interaction F (1.95, 50.76) = 0.24, p = .779, η_p^2 = .01, were found. In support of this polynomial contrasts indicated a significant quadratic trend of Condition and GA F (1, 26) = 5.91, p = .022, η_p^2 = .19. Overall, there is a decrease produced by the means from ‘Control’ (M = 4.88), over ‘Mother’ (M = 2.93), to ‘Father’ (M = 2.93) conditions. However, the ‘Stranger’ condition has a somewhat higher mean (M = 5.21) than producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.87). The means and standard errors can be examined in Table 3.65.

Table 3.65. Means and standard errors (SE) of fetuses ‘Arm movement’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	4.67	0.69	3.31	0.74		
Control	5.60	1.03	4.15	1.11	4.88	0.76
Mother	3.87	1.09	2.00	1.17	2.93	0.80
Father	3.87	1.1.09	2.00	1.17	2.93	0.80
Stranger	5.33	1.34	5.08	1.44	5.21	0.98

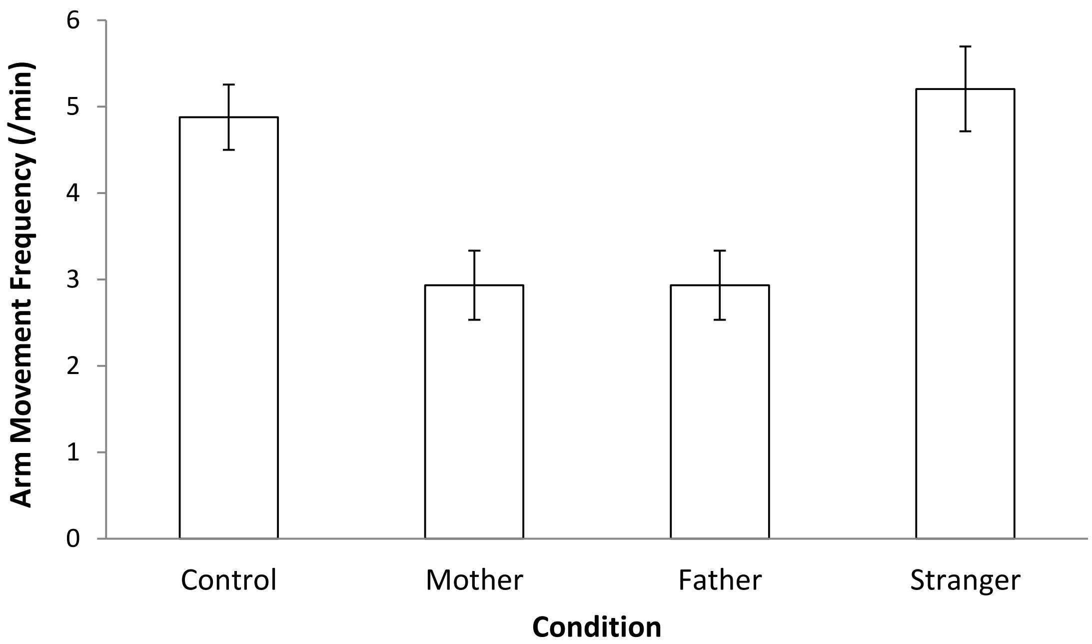

Figure 3.87. Average ‘Arm movement’ frequency (per minute) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: ‘Face press’ Frequency

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of ‘Face press’. There was a significant main effect of Condition, F (1.81, 46.93) = 2.13, p = .007, η_p^2 = .15. No main effects of GA F (1, 26) = 0.79, p = .384, η_p^2 = .03, or an interaction F (1.81, 46.93) = 0.85, p = .424, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 6.27, p = .016, η_p^2 = .17, of Condition. Overall, an increase is produced by the means from ‘Control’ (M = 0.48), over ‘Mother’ (M = 1.00), to ‘Father’ (M = 1.00). However, the ‘Stranger’ condition has a somewhat lower mean (M = 0.56) producing the quadratic trend.

Post-hoc pairwise comparison of the Condition main effect showed a tendency between ‘Control’ (M = 0.48) and ‘Mother’ (M = 1.00, p = .077) with a higher frequency of ‘Face press’ during maternal stimulation compared to ‘Control’. Fetuses also tended to increase ‘Face press’ frequency during fathers’ touch (M = 1.00) compared to ‘Control’ (M = 0.48, p = .077) (see Figure 3.88). No other significant differences were found between conditions. No further effects were found. The means and standard errors can be examined in Table 3.66.

Table 3.66. Means and standard errors (SE) of fetuses ‘Face press’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.90	0.22	0.62	0.24		
Control	0.80	0.22	0.15	0.23	0.48	0.16
Mother	1.07	0.30	0.92	0.33	1.00	0.22
Father	1.07	0.30	0.92	0.33	1.00	0.22
Stranger	0.67	0.24	0.46	0.26	0.56	0.18

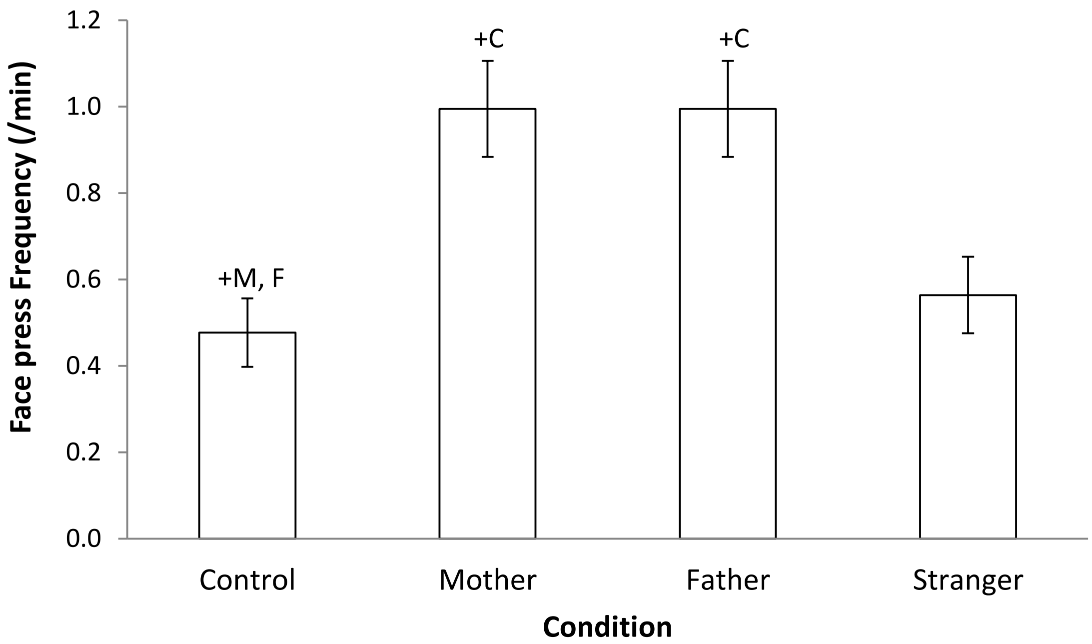

Figure 3.88. Average ‘Face press’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Face press’ Duration

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Face press’. There was a significant main effect of Condition, F (1.96, 50.82) = 4.35, p = .007, η_p^2 = .14. No main effects of GA F (1, 26) = 0.39, p = .538, η_p^2 = .02, or an interaction F (1.96, 50.82) = 1.36, p = .261, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 7.23, p = .012, η_p^2 = .22, of Condition. Overall, an increase is produced by the means from ‘Control’ (M = 21.78), to ‘Mother’ (M = 45.72) and the ‘Father’ condition (M = 45.72). However, the ‘Stranger’ condition has a somewhat lower mean (M = 28.21) producing the quadratic trend.

Post-hoc pairwise comparison of the Condition main effect showed a tendency between ‘Control’ (M = 21.78) and ‘Mother’ (M = 45.72, p = .088) with a higher duration of ‘Face press’ during maternal stimulation compared to ‘Control’. Fetuses also tended to increase ‘Face press’ duration during fathers’ touch (M = 45.72) compared to ‘Control’ (M = 21.78, p = .088) (see Figure 3.89). No further effects were found. The means and standard errors can be examined in Table 3.67.

Table 3.67. Means and standard errors (SE) of fetuses ‘Face press’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	39.94	10.02	30.77	10.76		
Control	35.86	10.07	7.69	10.81	21.78	7.39
Mother	45.29	13.19	46.15	14.17	45.72	9.68
Father	45.29	13.19	46.15	14.17	45.72	0.68
Stranger	33.33	12.93	23.08	12.92	28.21	8.83

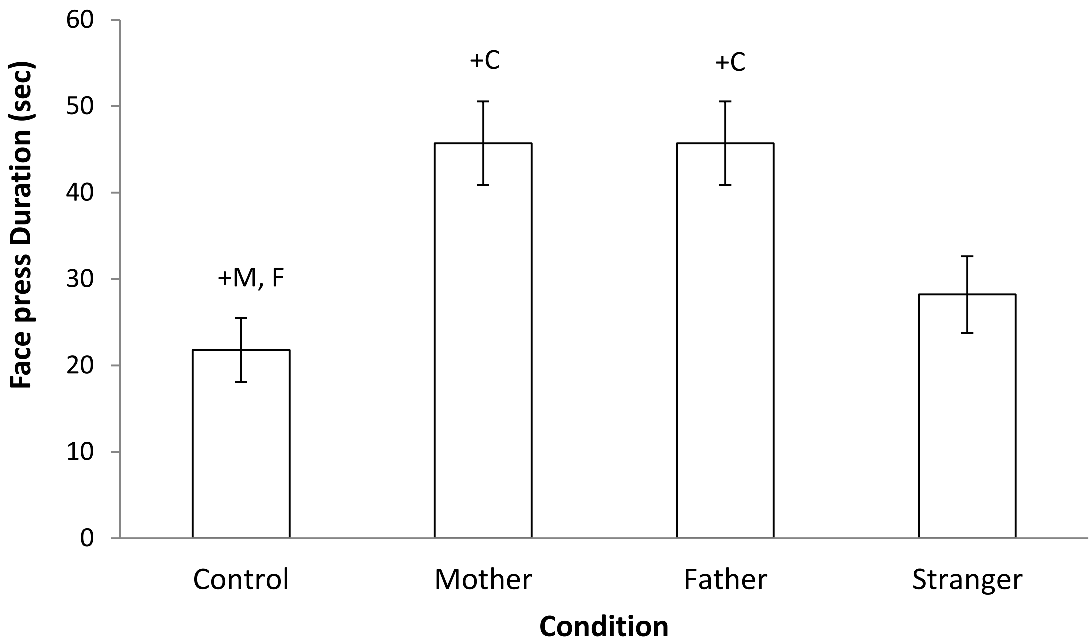

Figure 3.89. Average ‘Face press’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: ‘Mouth movement’ Frequency

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Mouth movements'. Results showed a significant main effect of Condition *F* (1.69, 43.96) = 4.37, *p* = .024, η_p^2 = .14, and a significant interaction *F* (1.69, 43.96) = 4.37, *p* = .024, η_p^2 = .14. No main effect of GA *F* (1, 26) = 0.15, *p* = .702, η_p^2 = .01, was found. Examination of the means of the main effect of Condition suggests that fetuses moved their mouth significantly different between Conditions regardless of GA, and the interaction revealed that 'Mouth movement' frequency depends upon Condition and GA. Polynomial contrasts indicated, in support of this, a significant quadratic trend *F* (1, 27) = 4.57, *p* = .042, η_p^2 = .15, for Condition. Overall, there is a decrease produced by the means from 'Control' (M = 1.03) to 'Mother' (M = 0.76) and 'Father' (M = 0.76). However, the 'Stranger' condition has a somewhat higher mean compared to all conditions (M = 2.23) producing the quadratic trend. A significant quadratic trend *F* (1, 27) = 4.57, *p* = .042, η_p^2 = .15, was found for the interaction.

Post-hoc pairwise comparison of the Condition main effect did not reveal any further effects (see Figure 3.90)**.** Post-hoc pairwise comparison of the interaction between Condition and GA revealed a significant difference for younger fetuses between 'Control' and 'Stranger' conditions, with more 'Mouth movements' in 'Stranger' (M = 3.07) compared to 'Control' (M = 0.67, *p* = .035). Younger fetuses increased 'Mouth movement' frequency significantly in 'Stranger' (M = 3.07) compared to 'Mother' (M = 0.13, *p* = .007) and 'Father' (M = 0.67, *p* = .007) conditions (see Figures 3.91 and 3.92). No further effects were found. The means and standard errors can be examined in Table 3.68.

Table 3.68. Means and standard errors (SE) on the frequency of fetuses ‘Mouth movements’ across conditions.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.39	0.73	2.00	0.68		
Control	0.67	0.61	1.39	0.65	1.03	0.45
Mother	0.13	0.78	1.39	0.84	0.76	0.57
Father	0.13	0.78	1.39	0.84	0.76	0.57
Stranger	3.07	0.93	1.39	1.00	2.23	0.68

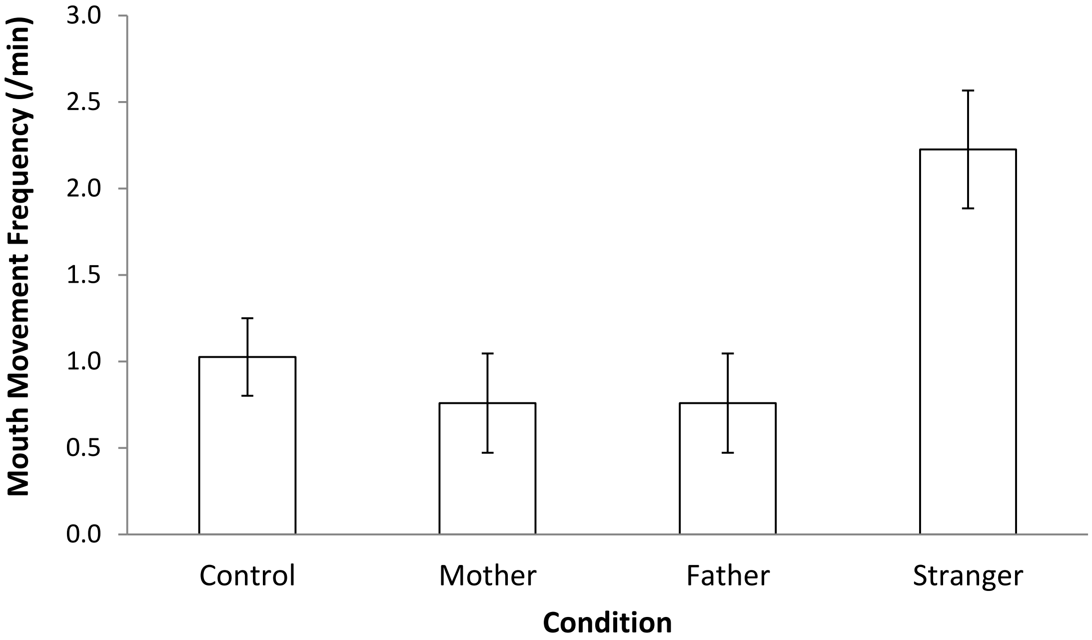

Figure 3.90. Average ‘Mouth movement’ frequency (per minute) including standard errors for each condition.

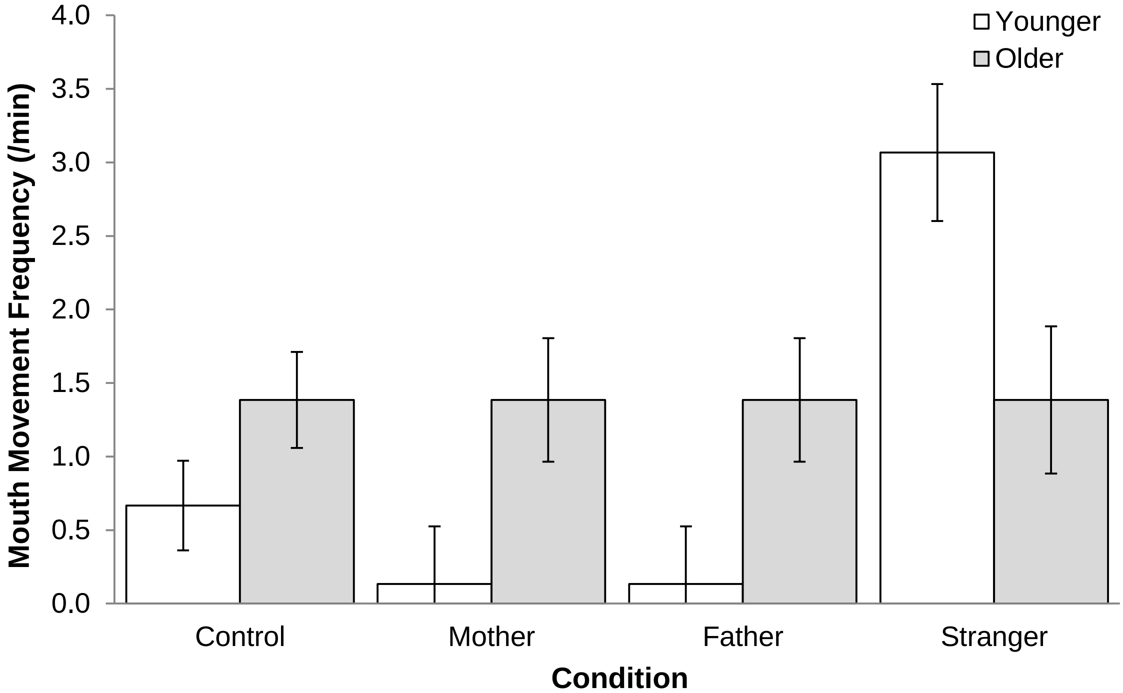

Figure 3.91. Average ‘Mouth movement’ frequency (per minute) including standard errors for each condition.

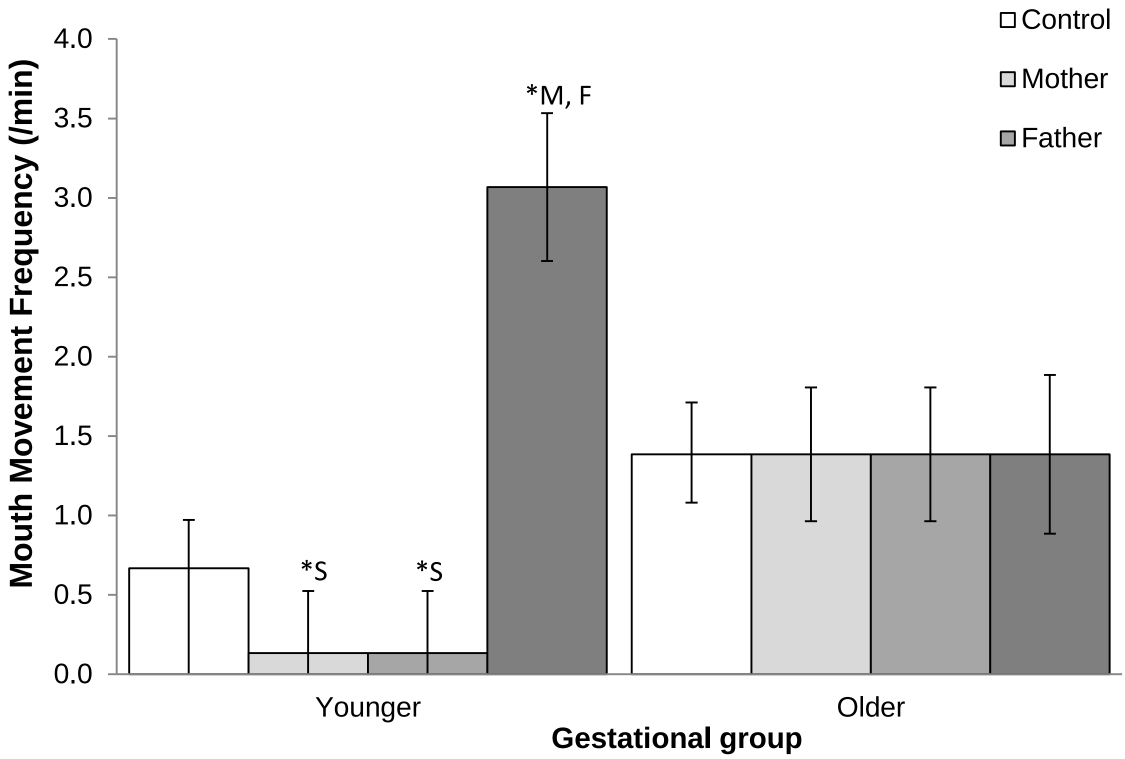

Figure 3.92. Average ‘Mouth Movement’ frequency (per minute) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

Mixed-design ANOVA Condition*GA: 'Mouth movement' Duration

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Mouth movements'. Results showed a significant interaction F (1.29, 33.45) = 5.20, p = .022, η_p^2 = .17. Neither a main effect of Condition F (1.29, 33.45) = 1.38, p = .256, η_p^2 = .05, nor a main effect of GA F (1, 26) = 0.15, p = .702, η_p^2 = .01, were found. Polynomial contrasts indicated, in support of this, a significant linear trend F (1, 27) = 5.79, p = .023, η_p^2 = .18, quadratic trend F (1, 27) = 4.27, p = .049, η_p^2 = .14, and cubic trend F (1, 27) = 5.79, p = .023, η_p^2 = .18, for the interaction.

Post-hoc pairwise comparison of the interaction revealed a tendency for an increase in mouth duration for younger fetuses in 'Stranger' (M = 17.26) compared to 'Mother' (M = 0.10, p = .080), as well as 'Father' (M = 0.10) and 'Control' (M = 3.98, p = .080) (see Figures 3.93 and 3.94). No further effects were found. The means and standard errors can be examined in Table 3.69.

Table 3.69. Means and standard errors (SE) on the duration of fetuses 'Mouth movements' across conditions.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	5.36	4.36	10.41	4.68		
Control	3.98	6.00	14.86	6.45	9.42	4.40
Mother	0.10	4.99	10.76	5.36	5.43	3.66
Father	0.10	4.99	10.76	5.36	5.43	3.66
Stranger	17.26	4.97	5.25	5.34	11.25	3.65

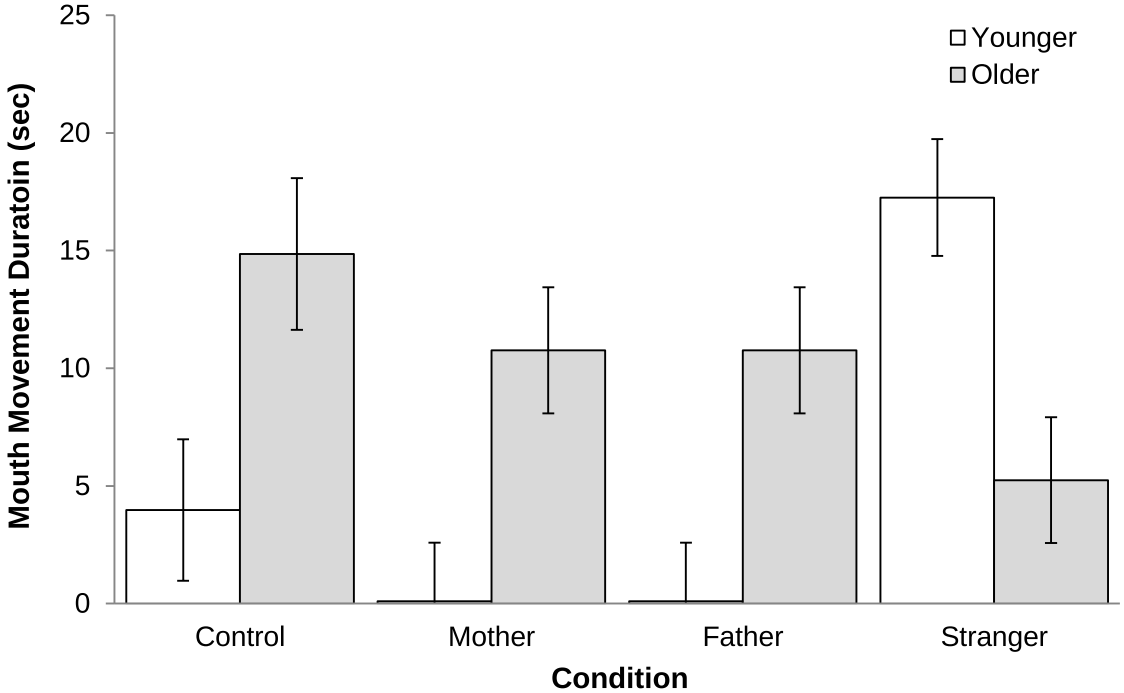

Figure 3.93. Average ‘Mouth movement’ duration (in seconds) including standard errors for each condition.

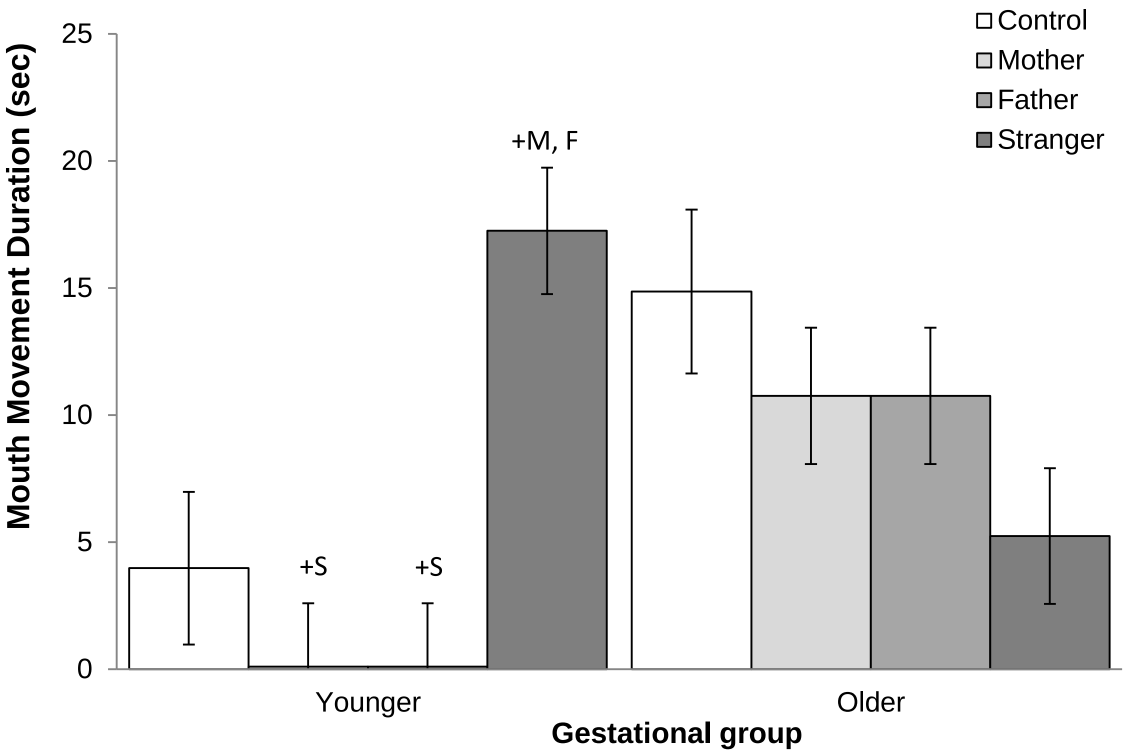

Figure 3.94. Average ‘Mouth Movement’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10).

60-90s Interval analysis combined

Repeated-measures ANOVA Condition: ‘Self-touch’ Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Self-touch’ duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (3, 81) = 4.88, p = .004, η_p^2 = .15. Examination of the means suggests that fetuses altered ‘Self-touch’ duration between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 10.66, p = .003, η_p^2 = .28. Overall, there is a decrease produced by the means from ‘Control’ (M = 8.47), to ‘Mother’ (M = 4.91), followed by an increase to ‘Father’ (M = 7.09), and ‘Stranger’ (M = 8.10) producing the quadratic trend.

Post-hoc pairwise comparison of the main effect of Condition revealed a significant difference between ‘Mother’ and ‘Control’ conditions, with longer ‘Self-touch’ duration during ‘Control’ (M = 8.47) compared to ‘Mother’ (M = 4.91, p = .004) implying that the fetus touched itself longer during ‘Control’. A significant difference was found between ‘Mother’ and ‘Stranger’, with fetuses touching their own body longer during ‘Stranger’ (M = 8.10) compared to ‘Mother’ (M = 4.91, p = .046) (see Figure 3.95). No other effects were found. The means and standard errors can be examined in Table 3.70.

Table 3.70. Means and standard errors (SE) on the duration of fetuses ‘Self-touch’ across conditions.

	Control	Mother	Father	Stranger
Mean	8.47	4.91	7.09	8.10
SE	0.56	0.88	0.81	0.63

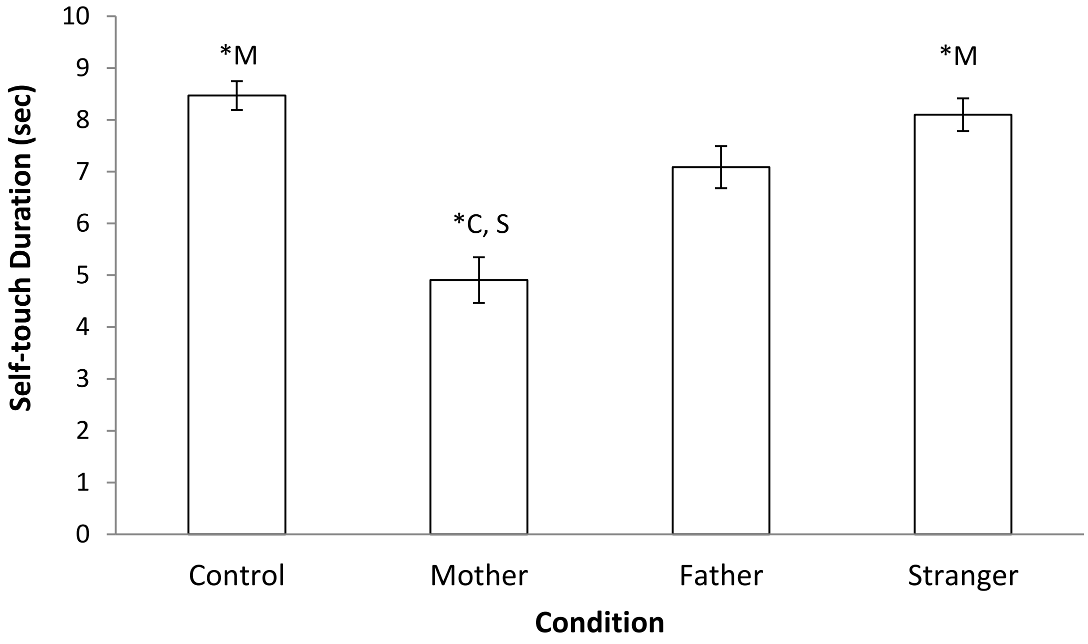

Figure 3.95. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (*< .05).

Repeated-measures ANOVA Condition: ‘External Touch’ Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘External Touch’ duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a marginally significant main effect of Condition F (3, 81) = 2.25, p = .088, η_p^2 = .08. Examination of the means suggests that fetuses altered ‘External Touch’ duration between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 11.05, p = .003, η_p^2 = .29. Overall, there is an increase produced by the means from ‘Control’ (M = 3.59), to ‘Mother’ (M = 6.63), followed by a slight decrease to ‘Father’ (M = 6.56), and ‘Stranger’ (M = 4.47) producing the quadratic trend.

The post-hoc pairwise comparison revealed no further effects (see Figure 3.96). The means and standard errors can be examined in Table 3.71.

Table 3.71. Means and standard errors (SE) on the duration of fetuses 'External Touch' across conditions.

	Control	Mother	Father	Stranger
Mean	3.59	6.63	6.56	4.47
SE	0.96	1.36	1.27	1.22

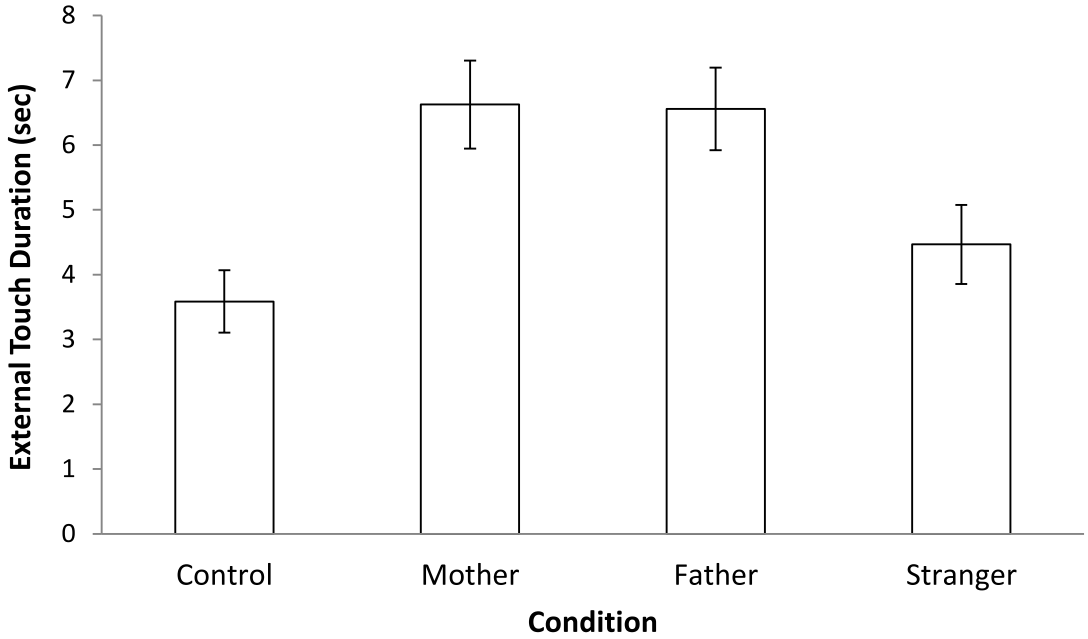

Figure 3.96. Average 'External Touch' duration (in seconds) including standard errors for each condition.

Repeated-measures ANOVA Condition: 'Inactivity/Resting' Frequency

A repeated-measures ANOVA, using Huynh-Feldt correction, was conducted to assess whether there are differences in 'Inactivity/Resting' frequency between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (2.51, 67.84) = 3.98, p = .016, η_p^2 = .13. Examination of the means suggests that fetuses altered 'Inactivity/Resting' frequency between Conditions. Polynomial contrasts indicated, in support of this, a significant cubic trend, F (1, 27) = 11.82, p = .002, η_p^2 = .31. Overall, there is a decrease produced by the means from 'Control' (M

= 1.21), to ‘Mother’ (M = 0.36), followed by an increase to ‘Father’ (M = 1.21), and ‘Stranger’ (M = 1.21) producing the cubic trend.

Post-hoc pairwise comparison revealed a significant difference between ‘Control’ and ‘Mother’ conditions, with a higher ‘Inactivity/Resting’ frequency during ‘Control’ compared to ‘Mother’ implying that the fetus was more active when the mother (M = 0.36) touched compared to ‘Control’ (M = 1.21, p = .047). A significant difference was found between ‘Mother’ and ‘Father’, with an increased ‘Inactivity/Resting’ for ‘Father’ (M = 1.21) compared to ‘Mother’ again implying that the fetus was more active during maternal touch (M = 0.36, p = .003). A tendency was found between ‘Mother’ and ‘Stranger’, with increased fetal activity during ‘Mother’ (M = 0.36) and an increased ‘Inactivity/Resting’ during ‘Stranger’ (M = 1.21, p = .094) (see Figure 3.97). No other effects were found. The means and standard errors can be examined in Table 3.72.

Table 3.72. Means and standard errors (SE) on the frequency of fetuses ‘Inactivity/Resting’ across conditions.

	Control	Mother	Father	Stranger
Mean	1.21	0.36	1.21	1.21
SE	0.30	0.15	0.26	0.30

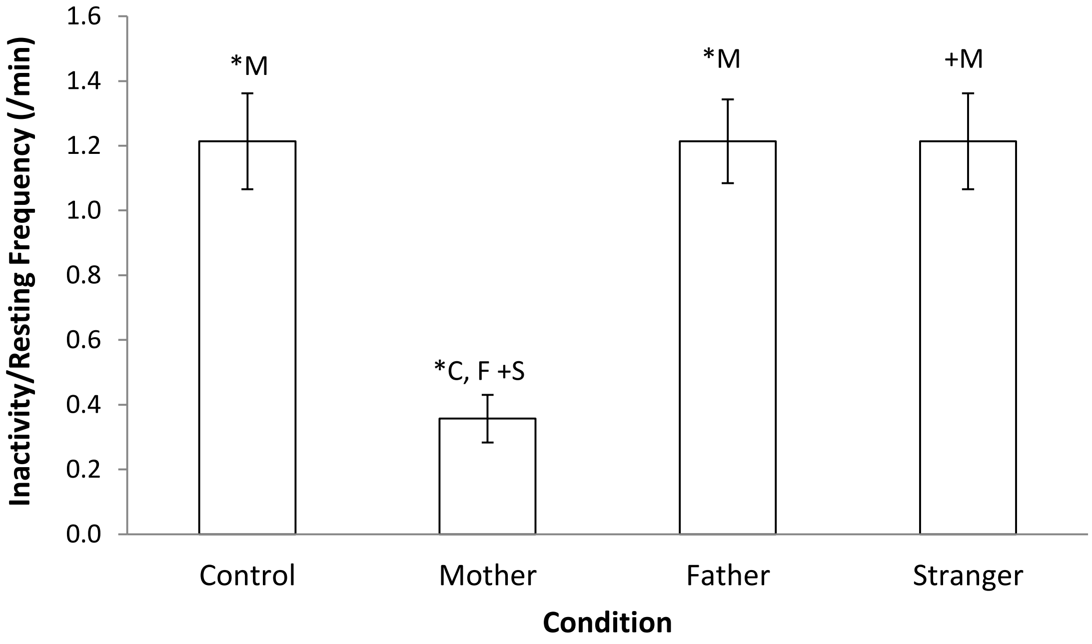

Figure 3.97. Average ‘Inactivity/Resting’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Repeated-measures ANOVA Condition: ‘Inactivity/Resting’ Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Inactivity/Resting’ duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant a main effect of Condition F (3, 81) = 2.80, p = .045, η_p^2 = .09. Examination of the means suggests that fetuses altered ‘Inactivity/Resting’ duration between Conditions. Polynomial contrasts indicated, in support of this, a significant cubic trend, F (1, 27) = 5.88, p = .022, η_p^2 = .18. Overall, there is a decrease produced by the means from ‘Control’ (M = 3.70), to ‘Mother’ (M = 1.70), followed by an increase to ‘Father’ (M = 4.77), and ‘Stranger’ (M = 4.42) producing the cubic trend.

Post-hoc pairwise comparison revealed a marginally significant difference between ‘Mother’ and ‘Father’ conditions, with a longer ‘Inactivity/Resting’ duration during father’s touch compared to ‘Mother’ implying that the fetus was more active when the mother (M = 1.70) touched compared to the father (M = 4.77, p = .058) (see Figure 3.98). No further effects were found. The means and standard errors can be examined in Table 3.73.

Table 3.73. Means and standard errors (SE) on the duration of fetuses 'Inactivity/Resting' across conditions.

	Control	Mother	Father	Stranger
Mean	3.70	1.70	4.77	4.42
SE	0.98	0.71	1.01	0.93

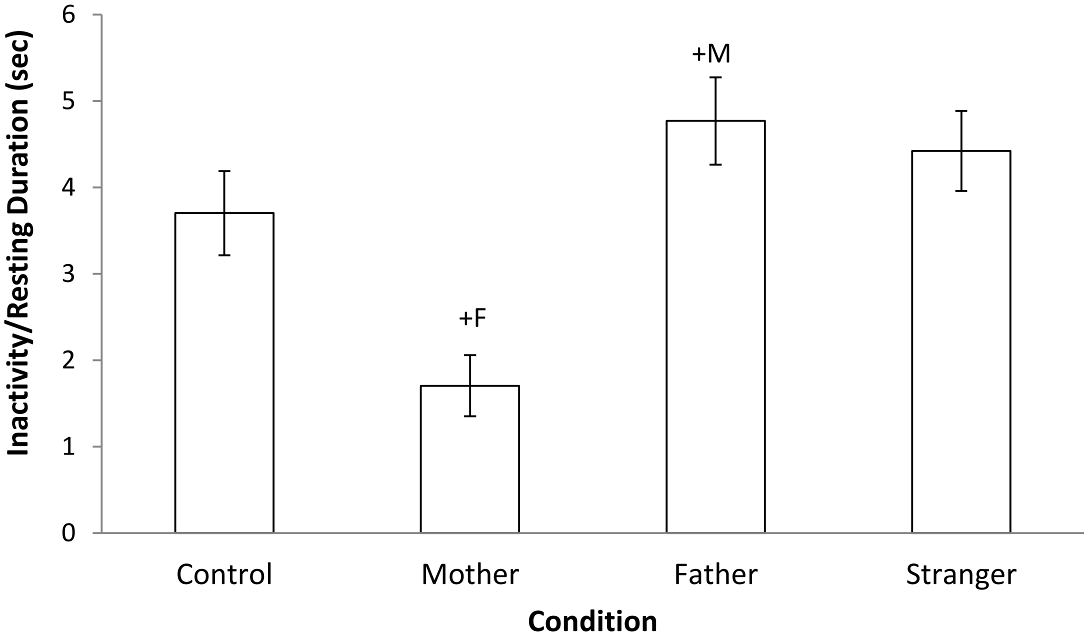

Figure 3.98. Average 'Inactivity/Resting' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Self-touch' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Self-touch'. Results showed a significant of the main effect of Condition F (3, 78) = 4.94, p = .003, η_p^2 = .16. No significant interaction between Condition and GA, F (3, 78) = 1.10, p = .355, η_p^2 = .04, or main effect of GA F (1, 26) = 0.24, p = .878, η_p^2 < .001, were found. In support of this polynomial contrasts of the main effect of Condition show a significant quadratic trend F (1, 26) = 10.17, p = .004, η_p^2 = .28, and a marginally significant cubic trend F (1, 26) = 3.70, p = .065, η_p^2 = .13. Overall, there is a decrease produced by the means from 'Control' (M = 8.54) to the ‘Mother’ (M = 4.90) followed by an increase to ‘Father’ (M = 7.11) and ‘Stranger’ (M = 8.04) producing quadratic and cubic trends.

Post-hoc pairwise comparison of the main effect of Condition, using Bonferroni corrections, revealed a significant difference between ‘Control’ and ‘Mother’, with longer ‘Self-touch’ durations during ‘Control’ (M = 8.54) compared to ‘Mother’ (M = 4.90, p = .003). A marginally significant difference was found between ‘Mother’ and ‘Stranger’, with longer ‘Self-touch’ durations during ‘Stranger’ (M = 8.04) compared to ‘Mother’ (M = 4.90, p = .057) (see Figure 3.99). No further effects were found. The means and standard errors can be examined in Table 3.74.

Table 3.74. Means and standard errors (SE) of fetuses ‘Self-touch’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.09	0.52	7.21	0.56		
Control	7.60	0.74	9.47	0.79	8.54	0.54
Mother	4.98	1.22	4.83	1.31	4.90	0.90
Father	6.85	1.13	7.37	1.21	7.11	0.83
Stranger	8.92	0.84	7.15	0.90	8.04	0.62

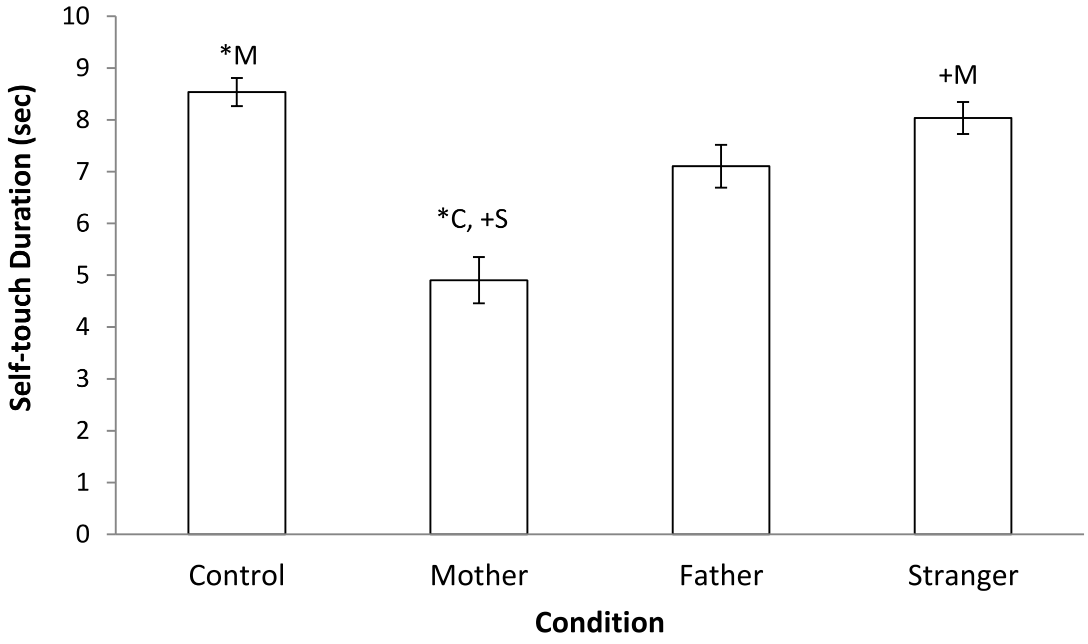

Figure 3.99. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: ‘External Touch’ Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘External Touch’. The main effect of Condition indicates a marginally significant difference, F (3, 78) = 2.40, p = .074, η_p^2 = .09. Neither a main effect of GA F (1, 26) = 1.04, p = .317, η_p^2 = .04, nor an interaction effect F (3, 78) = 1.29, p = .285, η_p^2 = .05, were found. In support of this polynomial contrasts indicated a significant quadratic trend F (1, 26) = 11.26, p = .002, η_p^2 = .30, of Condition, indicating a decrease from ‘Control’ (M = 3.41) to ‘Mother’ (M = 6.58), followed by a slight decrease to ‘Father’ (M = 6.53) and ‘Stranger’ (M = 4.48).

Post-hoc pairwise comparison of the Condition main effect revealed no further effects (see Figure 3.100). No further effects were found. The means and standard errors can be examined in Table 3.75.

Table 3.75. Means and standard errors (SE) of fetuses 'External Touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	6.10	1.14	4.40	1.22		
Control	5.91	1.16	0.91	1.25	3.41	0.85
Mother	7.26	1.88	5.90	2.02	6.58	1.38
Father	6.91	1.77	6.15	1.90	6.53	1.30
Stranger	4.33	1.70	4.62	1.82	4.48	1.25

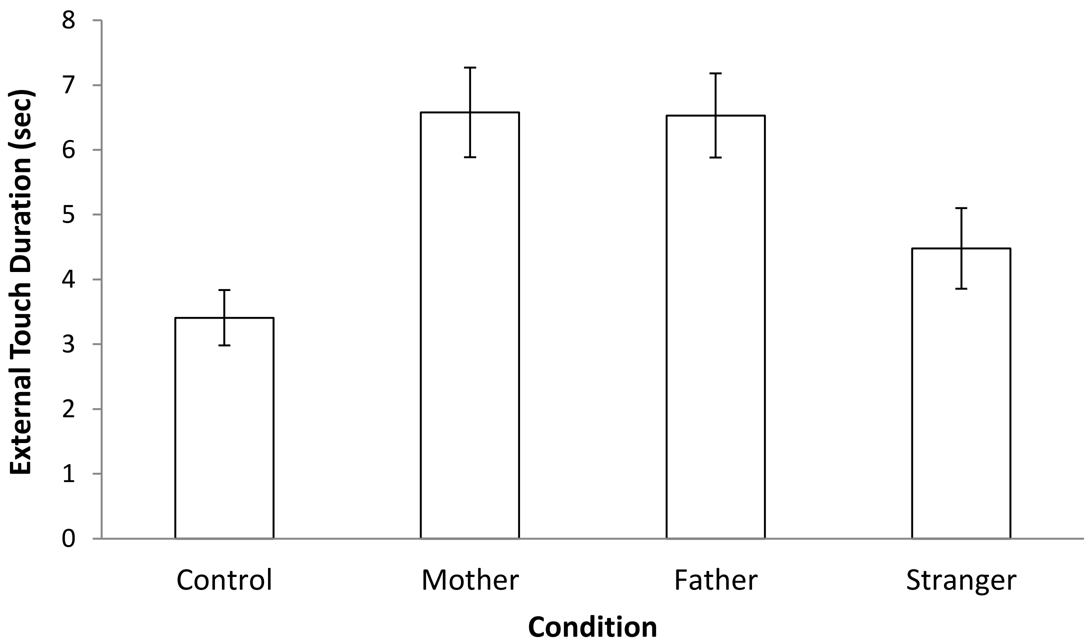

Figure 3.100. Average 'External Touch' duration (in seconds) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: ‘Inactivity/Resting’ Frequency

A mixed-design ANOVA, using Huynh-Feldt correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Inactivity/Resting’. There was a significant main effect of Condition, F (2.57, 66.87) = 3.90, p = .017, η_p^2 = .13. Neither a main effect of GA F (1, 26) = 0.36, p = .557, η_p^2 = .01, nor an interaction effect F (2.57, 66.87) = 0.93, p = .422, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 11.58, p = .002, η_p^2 = .31, of Condition, indicating a decrease from ‘Control’ (M = 1.20) to ‘Mother’ (M = 0.35), followed by an increase to ‘Father’ (M = 1.20), and ‘Stranger’ (M = 1.23).

Post-hoc pairwise comparison of the Condition main effect showed a significant difference between ‘Mother’ and ‘Father’ with a higher frequency of ‘Inactivity/Resting’ in ‘Father’ (M = 1.20) compared to ‘Mother’ (M = 0.35, p = .004). Marginally significant results were found between ‘Control’ and ‘Mother’, with higher frequencies of ‘Inactivity/Resting’ for ‘Control’ (M = 1.20) compared to ‘Mother’ (M = 0.35, p = .059). Furthermore, marginally significant differences were found between ‘Mother’ and ‘Stranger’, with higher frequencies of ‘Inactivity/Resting’ in ‘Stranger’ (M = 1.23) compared to ‘Mother’ (M = 0.35, p = .094) (see Figure 3.101). No further effects were found. The means and standard errors can be examined in Table 3.76.

Table 3.76. Means and standard errors (SE) of fetuses 'Inactivity/Resting' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	1.10	0.25	0.89	0.27		
Control	1.47	0.41	0.92	0.44	1.20	0.30
Mother	0.40	0.21	0.31	0.22	0.35	0.15
Father	1.47	0.35	0.92	0.38	1.20	0.26
Stranger	1.07	0.41	1.39	0.44	1.23	0.30

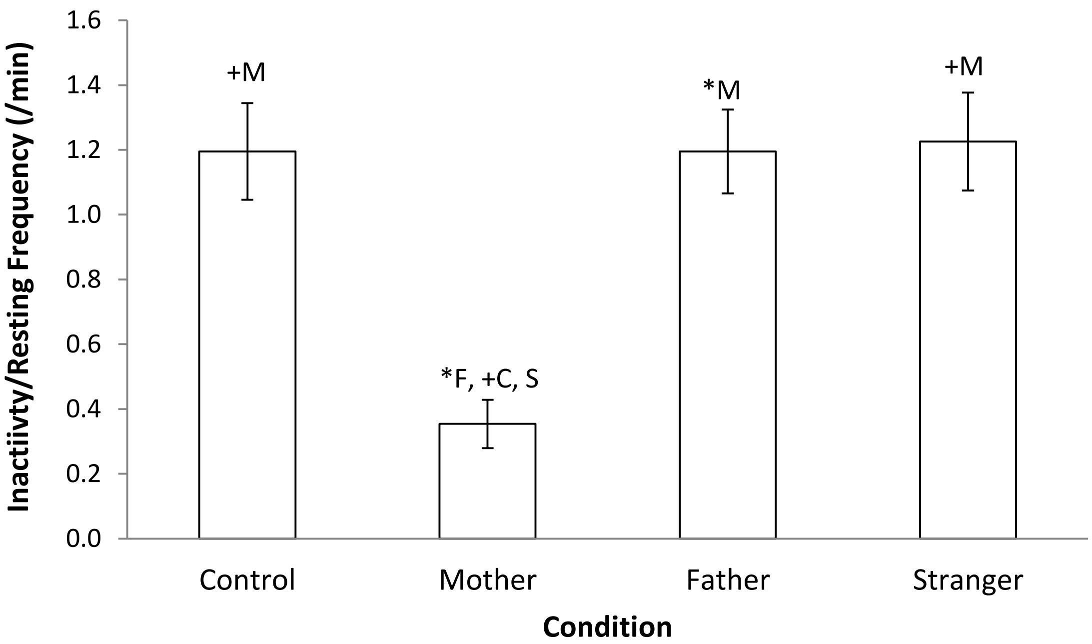

Figure 3.101. Average 'Inactivity/Resting' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: 'Inactivity/Resting' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Inactivity/Resting'. The main effect of Condition indicates a significant difference, F (3, 78) = 2.88, p = .041, η_p^2 = .10. Neither a main effect of GA F (1, 26) = 0.23, p = .639, η_p^2 = .01, nor an interaction effect F (3, 78) = 0.87, p = .458, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 5.58, p = .026, η_p^2 = .18, and a tendency for a linear trend of Condition F (1, 26) = 3.09, p = .091, η_p^2 = .11, indicating a decrease from 'Control' (M = 3.72) to 'Mother' (M = 1.68), followed by an increase to 'Father' (M = 4.76) and 'Stranger' (M = 4.52).

Post-hoc pairwise comparison of the Condition main effect showed a marginally significant difference between 'Mother' and 'Father' with a longer duration of 'Inactivity/Resting' in 'Father' (M = 4.76) compared to 'Mother' (M = 1.68, p = .066) (see Figure 3.102). No further effects were found. The means

Table 3.77. Means and standard errors (SE) of fetuses 'Inactivity/Resting' duration across conditions and gestational ages as well as pairwise comparisons.

and standard errors can be examined in Table 3.77.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.39	0.80	3.95	0.85		
Control	3.53	1.36	3.90	1.46	3.72	1.00
Mother	2.00	0.98	1.36	1.05	1.68	0.72
Father	4.90	1.41	4.62	1.51	4.76	1.03
Stranger	3.13	1.23	5.91	1.33	4.52	0.91

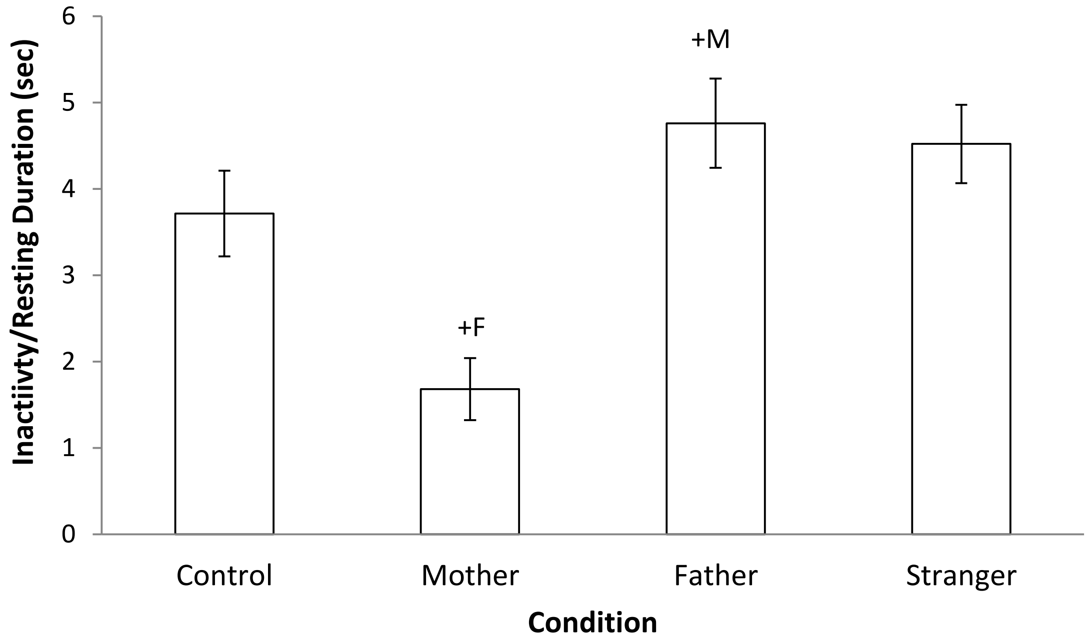

Figure 3.102. Average 'Inactivity/Resting' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

60-120s Interval

Repeated-measures ANOVA Condition: 'Arm movement' Frequency

A repeated-measures ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of 'Arm movements'. Results showed a tendency between Conditions F (3, 81) = 2.24, p = .090, η_p^2 = .08. Examination of the means suggests that fetuses tend to change the frequency of 'Arm movements' between Conditions. Polynomial contrasts indicated, in support of this, a significant cubic trend, F (1, 27) = 11.25, p = .002, η_p^2 = .29. Overall, there is an increase produced by the means from 'Control' (M = 4.29), to 'Mother' (M = 4.74), means decrease from 'Mother' to 'Father' (M = 2.71), and increase again for the 'Stranger' (M = 4.86) condition producing the cubic trend.

Post-hoc revealed a tendency between 'Mother' and 'Father', with more 'Arm movements' in 'Mother' (M = 4.74) compared to 'Father' (M = 2.71, p =

.060) (see Figure 3.103). The means and standard errors can be examined in Table 3.78.

Table 3.78. Means and standard errors (SE) on the frequency of fetuses ‘Arm movements’ across conditions.

	Control	Mother	Father	Stranger
Mean	4.29	4.74	2.71	4.86
SE	0.61	0.78	0.61	0.79

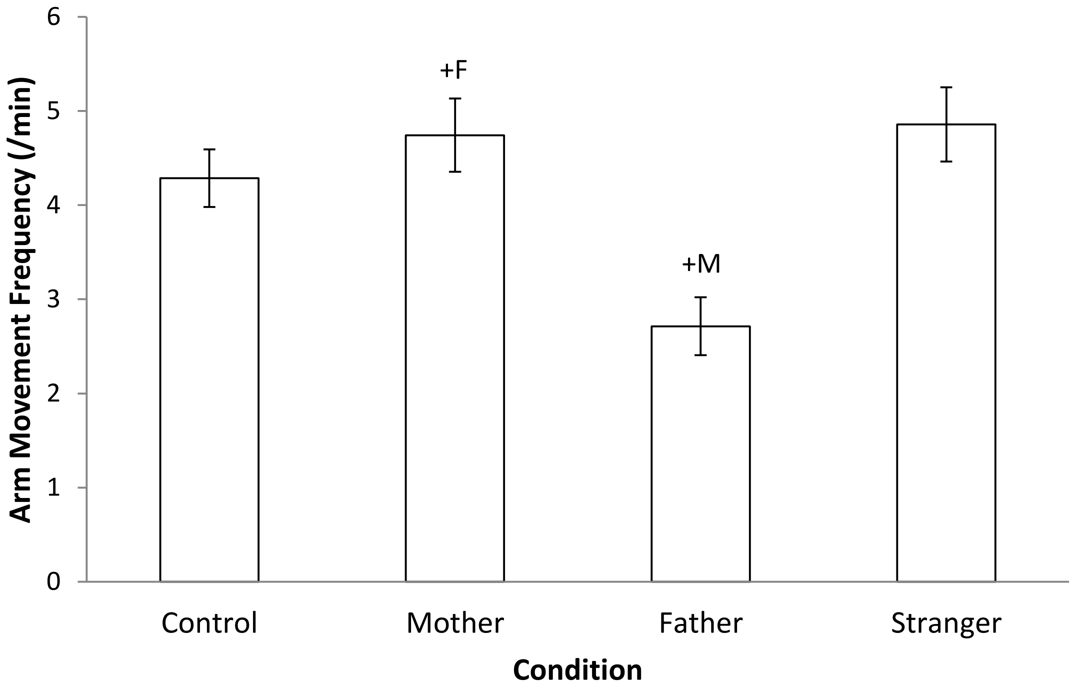

Figure 3.103. Average ‘Arm movement’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: ‘Body touch’ Frequency

A repeated-measures ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of ‘Body touch’. Results showed a tendency between Conditions *F* (3, 81) = 2.66, *p* = .054, η_p^2 = .09. Examination of the means suggests that fetuses tend to alter

'Body touch' frequency depending on Condition. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 6.35, p = .018, η_p^2 = .19. Overall, there is a decrease produced by the means from 'Control' (M = 0.75), to 'Mother' (M = 0.29). Means increase from 'Mother' to 'Father' (M = 0.39) and for 'Stranger' (M = 0.82) producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.104). The means and standard errors can be examined in Table 3.79.

Table 3.79. Means and standard errors (SE) on the frequency of fetuses 'Body touch' across conditions.

	Control	Mother	Father	Stranger
Mean	0.75	0.29	0.39	0.82
SE	0.20	0.11	0.13	0.24

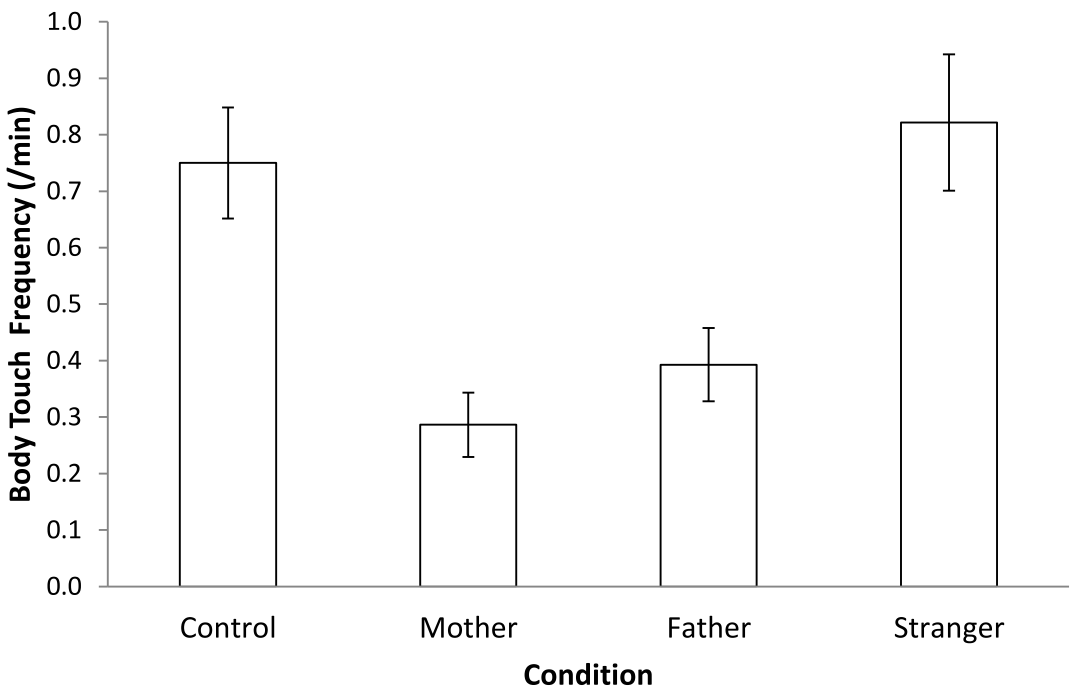

Figure 3.104. Average 'Body touch' frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: ‘Arms-crossed’ Frequency

A repeated-measures ANOVA, using Huynh-Feldt correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of ‘Arms-crossed’ behaviours. Results showed a significant between Conditions F (2.52, 67.93) = 3.22, p = .036, η_p^2 = .11. Examination of the means suggests that fetuses tend to alter arm-cross frequency depending on Condition. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 5.88, p = .022, η_p^2 = .18, and cubic trend (1, 27) = 5.19, p = .031, η_p^2 = .16. Overall, there is a decrease produced by the means from ‘Control’ (M = 0.50) to ‘Mother’ (M = 0.07). Means increase from ‘Mother’ to ‘Father’ (M = 0.32) and for ‘Stranger’ (M = 0.43) producing the quadratic and cubic trend.

The post-hoc pairwise comparison revealed a significant difference between ‘Control’ and ‘Mother’ (p = .008) with more ’Arms-crossed’ in ‘Control’ compared to ‘Mother’ (see Figure 3.105). No further effects were found. The means and standard errors can be examined in Table 3.80.

Table 3.80. Means and standard errors (SE) on the frequency of fetuses ‘Arms-crossed’ across conditions.

	Control	Mother	Father	Stranger
Mean	0.50	0.07	0.32	0.43
SE	0.12	0.05	0.12	0.14

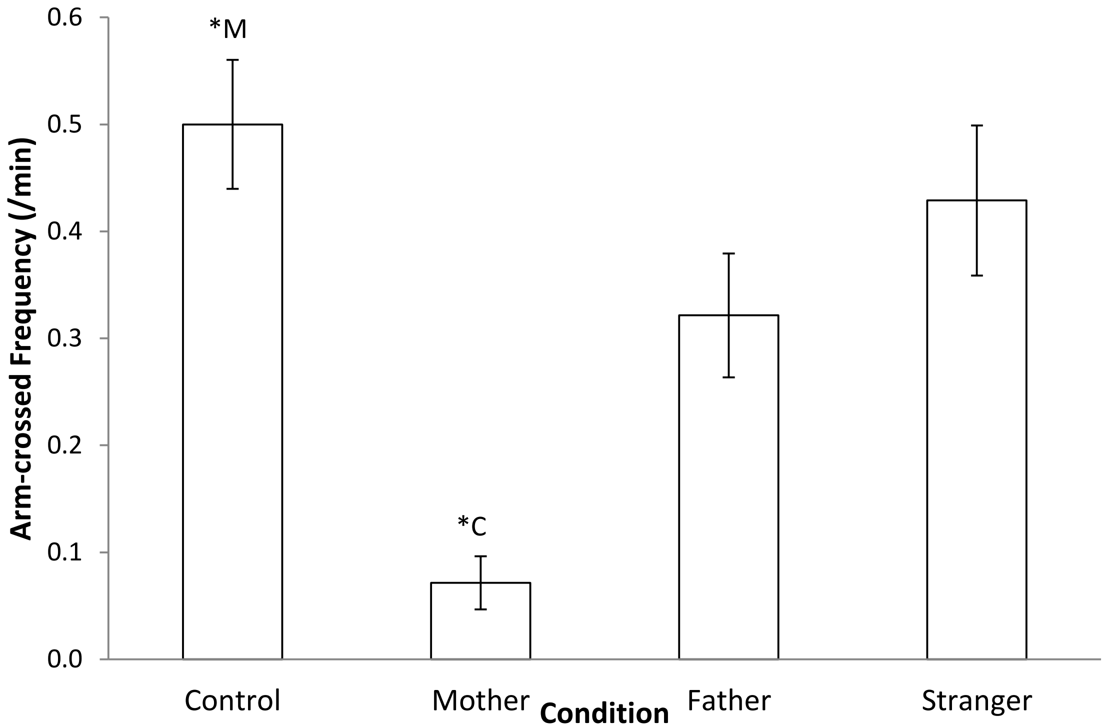

Figure 3.105. Average 'Arms-crossed' frequency (per minute) including standard errors for each condition (*< .05).

Repeated-measures ANOVA Condition: 'Hand movement' Duration

A repeated-measures ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the duration of 'Hand movements'. Results showed a tendency between Conditions F (1.13, 30.51) = 3.06, p = .086, η_p^2 = .10. Examination of the means suggests that fetuses tend to alter hand movement frequency depending on Condition. Polynomial contrasts indicated, in support of this, a tendency for a cubic trend, F (1, 27) = 3.44, p = .074, η_p^2 = .11. Overall, there is an increase produced by the means from 'Control' (M = 2.25) to 'Mother' (M = 11.43). Means decrease from 'Mother' to 'Father' (M = 1.45) and increase again slightly for 'Stranger' (M = 2.91), producing the cubic tendency.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.106). The means and standard errors can be examined in Table 3.81.

Table 3.81. Means and standard errors (SE) on the duration of fetuses ‘Hand movements’ across conditions.

	Control	Mother	Father	Stranger
Mean	2.25	11.43	1.45	2.91
SE	0.77	5.55	0.62	1.21

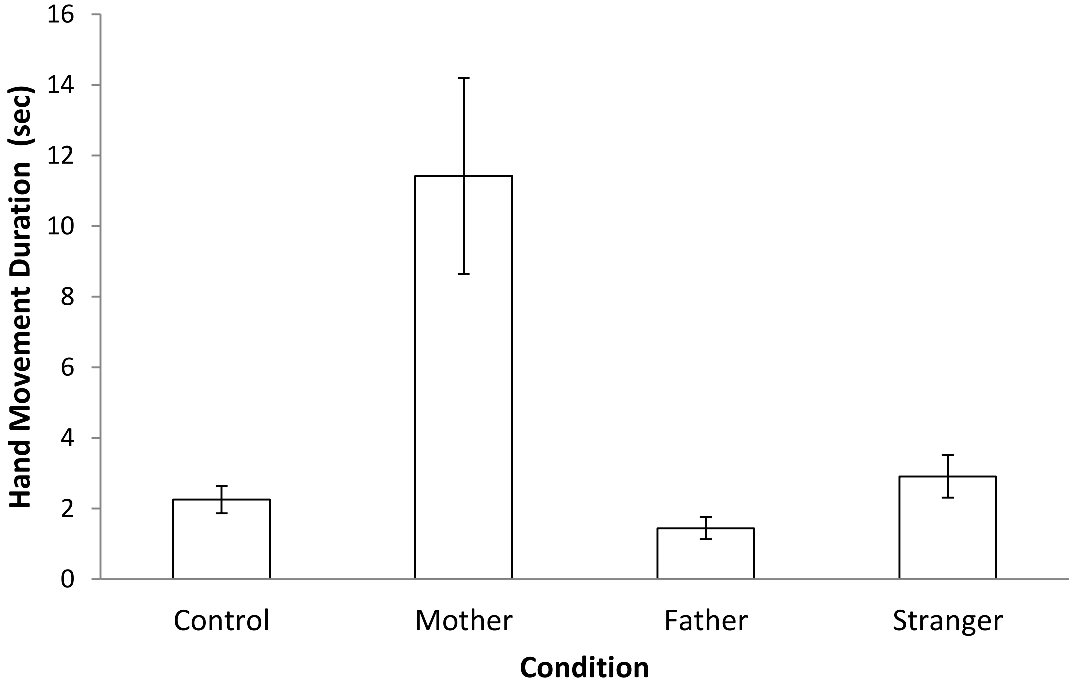

Figure 3.106. Average ‘Hand movement’ duration (in seconds) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: ‘Arm movement’ Frequency

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Arm movements’. The main effect of Condition indicates a trend, F (3, 78) = 2.18, p = .098, η_p^2 = .08. No significant main effect of GA F (1, 26) = 1.54, p = .226, η_p^2 = .06, or an interaction F (3, 78) = 0.29, p = .830, η_p^2 = .01, were found. In support of this polynomial contrasts indicated a significant cubic trend of Condition and GA F (1, 26) = 10.65, p = .003, η_p^2 = .29. Overall, there is a decrease produced by the means from ‘Control’ (M = 4.26) to

‘Mother’ (M = 4.67). ‘Father’ (M = 2.67) has a somewhat lower mean which is followed by an increase to ‘Stranger’ (M = 4.85), producing the cubic trend.

The post-hoc pairwise comparison revealed a tendency between ‘Mother’ and ‘Father’ Conditions, with fetuses moving arms more frequently during mother’s touch (M = 4.67) compared to fathers (M = 2.67, *p* = .074) (see Figure 3.107). No further effects were found. The means and standard errors can be examined in Table 3.82.

Table 3.82. Means and standard errors (SE) of fetuses ‘Arm movement’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	4.62	0.55	3.61	0.60		
Control	4.60	0.85	3.92	0.91	4.26	0.62
Mother	5.67	1.05	3.67	1.13	4.67	0.77
Father	3.20	0.84	2.15	0.90	2.68	0.62
Stranger	5.00	1.10	4.69	1.18	4.85	0.80

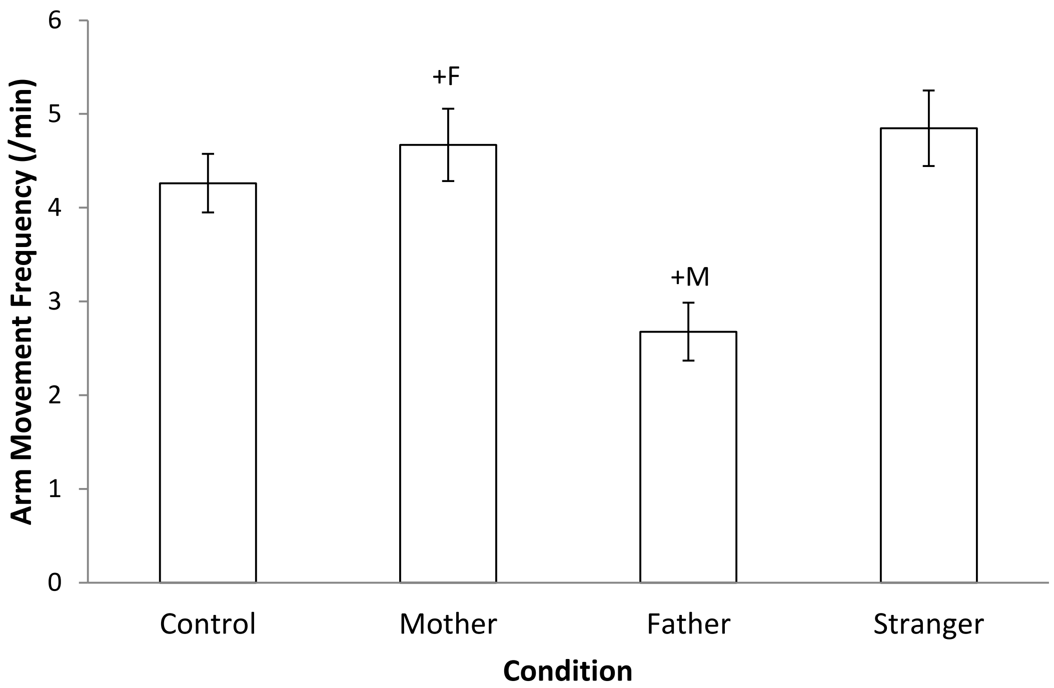

Figure 3.107. Average 'Arm movement' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Body touch' Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of 'Body touch'. Results showed a significant main effect of Condition F (3, 78) = 3.32, p = .024, η_p^2 = .11, and a significant interaction between Condition and GA, F (3, 78) = 3.33, p = .024, η_p^2 = .11. However, no significant main effect of GA F (1, 26) = 1.21, p = .282, η_p^2 = .04, was found. In support of this polynomial contrasts of the interaction showed a significant quadratic trend for Condition F (1, 26) = 9.11, p = .006, η_p^2 = .26, as well as a quadratic trend for the interaction of Condition and GA F (1, 26) = 7.09, p = .009, η_p^2 = .23. Overall there is a decrease from 'Control' (M = 0.77) to 'Mother' (M = 0.27). 'Father' (M = 0.39) has a somewhat lower mean which is followed by an increase in the 'Stranger' condition (M = 0.85), producing the quadratic trend.

Post-hoc pairwise comparison of the main effect of Condition showed a tendency between ‘Control’ and ‘Mother’, with more ‘Body touch’ during ‘Control’ (M = 0.77) than mothers’ touch (M = 0.27, *p* = .069) (see Figure 108).

Post-hoc pairwise comparison of the interaction revealed a tendency in ‘Mother’, where younger fetuses (M = 0.47) touched the body more compared to older fetuses (M = 0.08, *p* = 0.86). Likewise, a tendency was found in ‘Stranger’, with older fetuses (M = 1.31) touching the body more compared to younger fetuses (M = 0.40, *p* = .059). Older fetuses displayed a significant difference between ‘Control’ (M = 1.00) and ‘Mother’ (M = 0.08, *p* = .011), with more ‘Body touch’ during ‘Control’. A significant difference was found for older fetuses between mothers’ and strangers’ touch, with an increased ‘Body touch’ frequency during stranger’s touch (M = 1.31) compared to mothers’ (M = 0.77, *p* = .008) touch. Older fetuses also displayed a tendency between ‘Father’ and ‘Stranger’, with increased ‘Body touch’ frequency in ‘Stranger’ (M = 1.31) compared to ‘Father’ (M = 0.39, *p* = .093) (see Figures 3.109 and 3.110). No further effects were found. The means and standard errors can be examined in

Table 3.83. Means and standard errors (SE) of fetuses ‘Body touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

Table 3.83.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.45	0.15	0.69	0.16		
Control	0.53	0.27	1.00	0.29	0.77	0.20
Mother	0.47	0.15	0.08	0.16	0.27	0.11
Father	0.40	0.18	0.39	0.19	0.39	0.13
Stranger	0.40	0.31	1.31	0.34	0.85	0.23

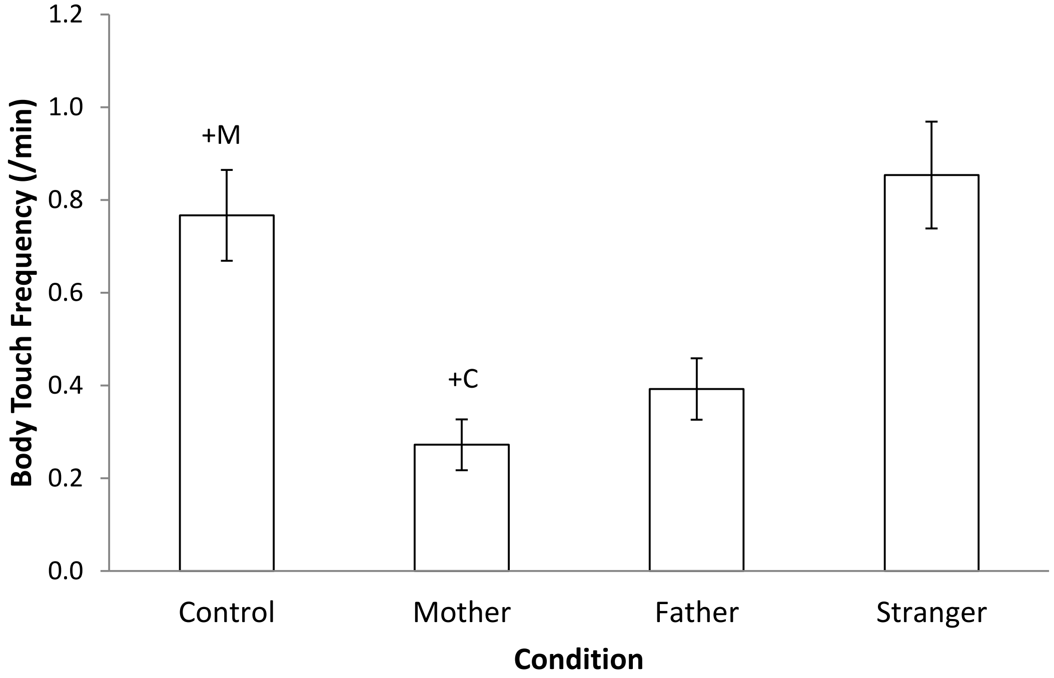

Figure 3.108. Average ‘Body touch’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

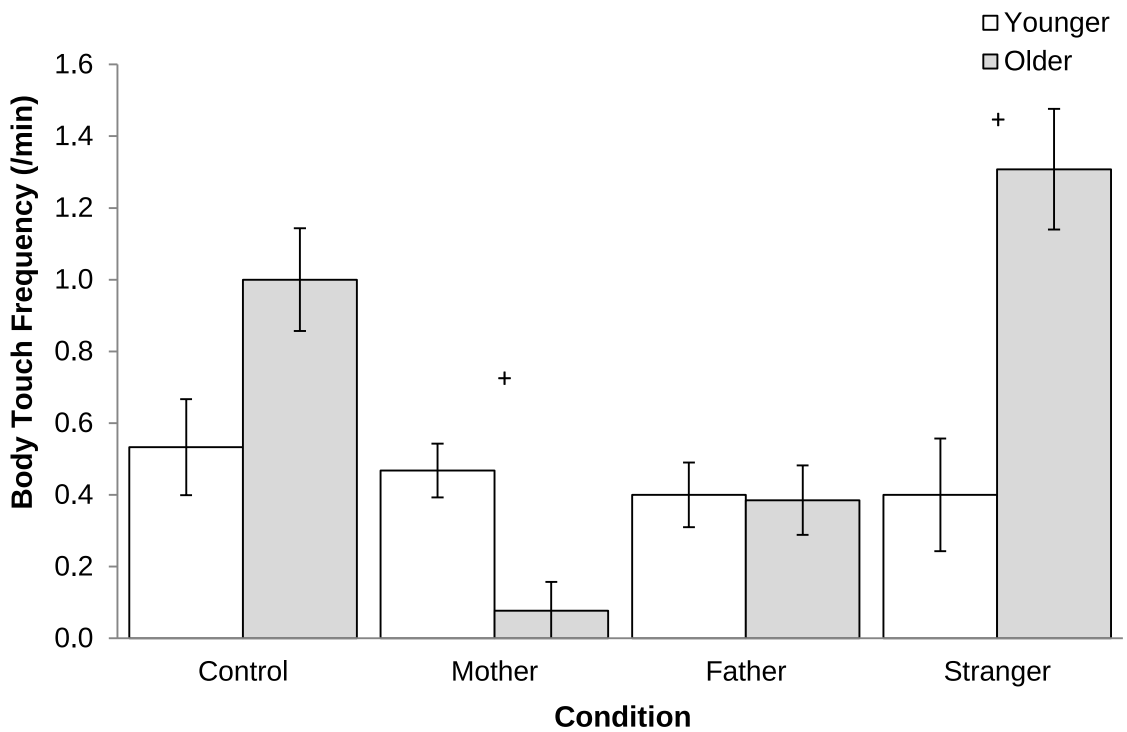

Figure 3.109. Average ‘Body touch’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

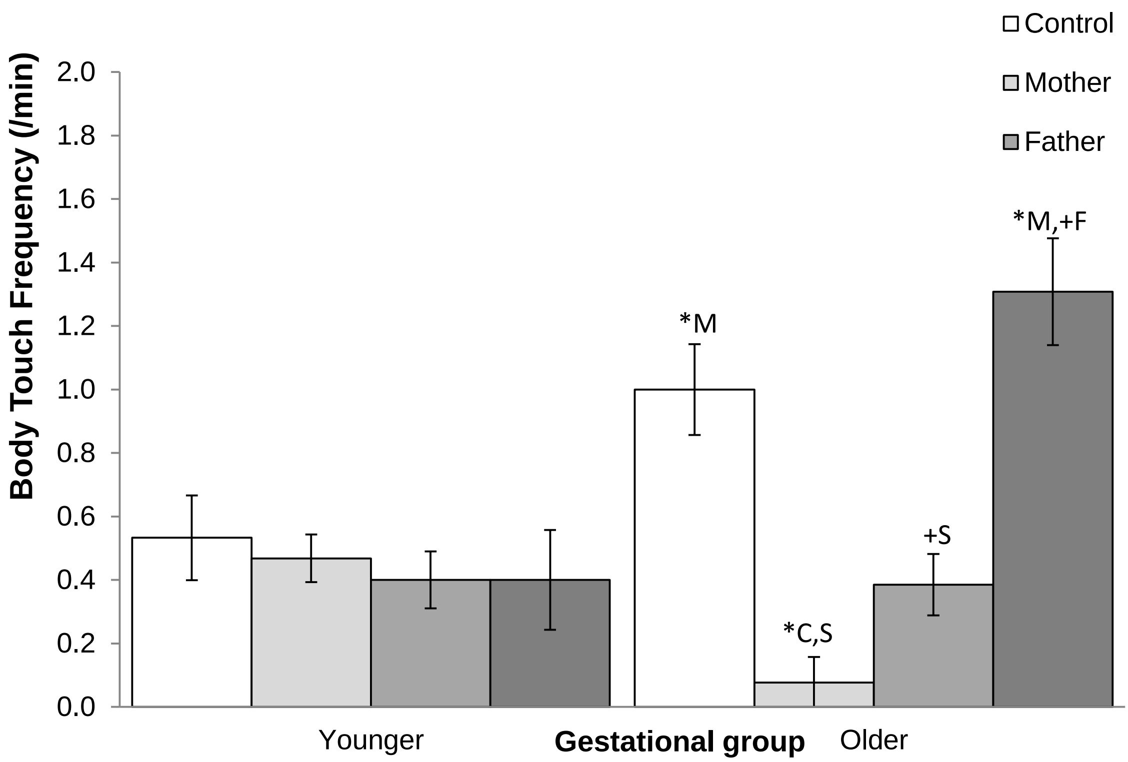

Figure 3.110. Average 'Body touch' frequency (in minutes) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: 'Uterus touch' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the durations of 'Uterus touch'. Results showed a tendency of main effect of Condition *F* (3, 78) = 2.18, *p* = .097, η_p^2 = .08. Neither an interaction between Condition and GA, *F* (3, 78) = 1.53, *p* = .212, η_p^2 = .06, nor a significant main effect of GA *F* (1, 26) = 0.08, *p* = .776, η_p^2 < .01, were found.

Post-hoc pairwise comparison of the main effect of Condition revealed no further effects (see Figure 3.111). The means and standard errors can be examined in Table 3.84.

Table 3.84. Means and standard errors (SE) of fetuses ‘Uterus touch’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	24.17	6.08	21.60	6.53		
Control	26.00	7.67	5.49	8.24	15.74	5.63
Mother	36.34	12.02	36.81	12.91	36.57	8.82
Father	24.06	10.18	16.81	10.93	20.44	7.47
Stranger	10.27	7.99	27.28	8.58	18.77	5.86

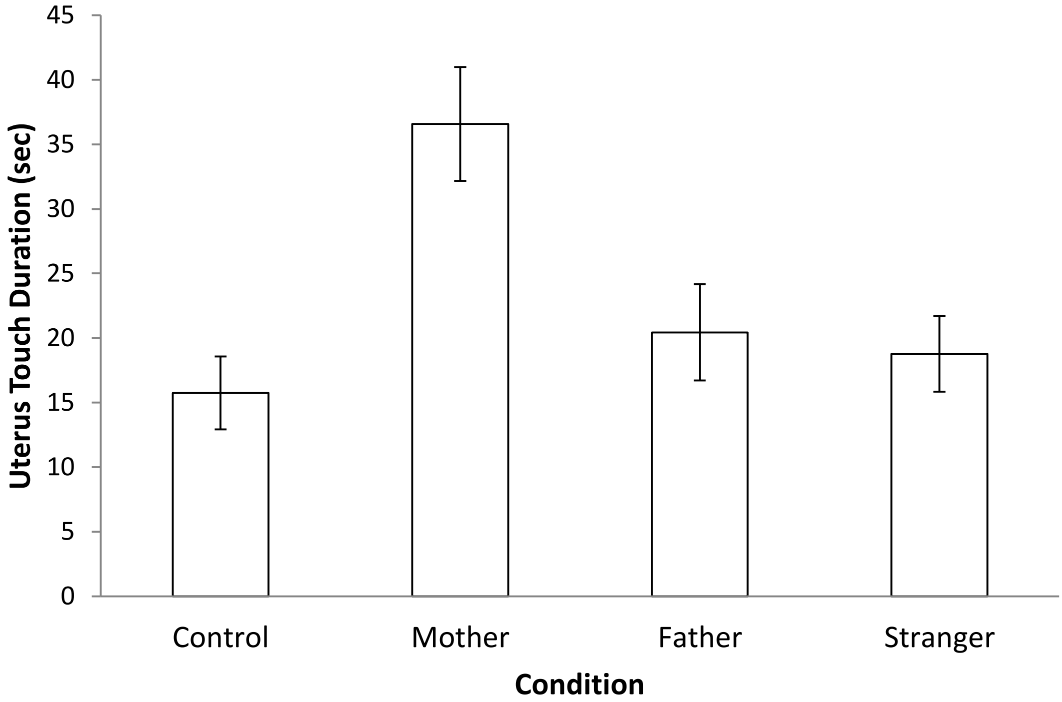

Figure 3.111. Average ‘Uterus touch’ duration (in seconds) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: ‘Arms-crossed’ Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of ‘Arms-crossed’ behaviour. Results showed a significant main effect of Condition *F* (3, 78) = 3.53, *p* = .019, η_p^2 = .12, and a tendency for an interaction between Condition and GA, *F* (3, 78) = 2.30, *p* = .083, η_p^2 = .08, however no significant main effect of GA *F* (1, 26) = 0.05, *p* = .828, η_p^2 < .01. In support of this polynomial contrasts of the Condition main effect showed a significant quadratic trend for Condition *F* (1, 26) = 6.86, *p* = .015, η_p^2 = .21, as well as a cubic trend *F* (1, 26) = 4.84, *p* = .037, η_p^2 = .16. Overall there is a decrease from ‘Control’ (M = 0.50) to ‘Mother’ (M = 0.07). ‘Father’ (M = 0.32) has a somewhat higher mean which is followed by an increase in the ‘Stranger’ condition (M = 0.45), producing the quadratic and cubic trend.

Post-hoc pairwise comparison of the main effect of Condition showed a significant difference between ‘Control’ and ‘Mother’, with more ‘Arms-crossed’ during ‘Control’ (M = 0.50) compared to mothers’ touch (M = 0.07, *p* = .010). A further tendency can be observed between ‘Mother’ and ‘Stranger’, with more ‘Arms-crossed’ during ‘Stranger’ (M = 0.45) compared to ‘Mother’ (M = 0.07, *p* = .096) (see Figure 3.112).

Post-hoc pairwise comparison of the interaction revealed a tendency in the ‘Stranger’ condition, with older fetuses (M = 0.69) displaying more ‘Arms-crossed’ compared to younger fetuses (M = 0.20, *p* = .080). Older fetuses had a tendency to show differences between ‘Control’ and ‘Mother’, with more ‘Arms-crossed’ in ‘Control’ (M = 0.46) compared to mother’s touch (M = 0.00, *p* = .096). A significant difference was found for older fetuses between ‘Mother’ and ‘Stranger’ conditions, with more ‘Arms-crossed’ in ‘Stranger’ (M = 0.69) compared to ‘Mother’ (M = 0.00, *p* = .021) (see Figures 3.113 and 3.114). No further effects were found. The means and standard errors can be examined in Table 3.85.

Table 3.85. Means and standard errors (SE) of fetuses 'Arms-crossed' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.32	0.09	0.35	0.10		
Control	0.53	0.17	0.46	0.18	0.50	0.12
Mother	0.13	0.07	0.00	0.07	0.07	0.05
Father	0.40	0.16	0.23	0.17	0.32	0.12
Stranger	0.20	0.18	0.69	0.20	0.45	0.14

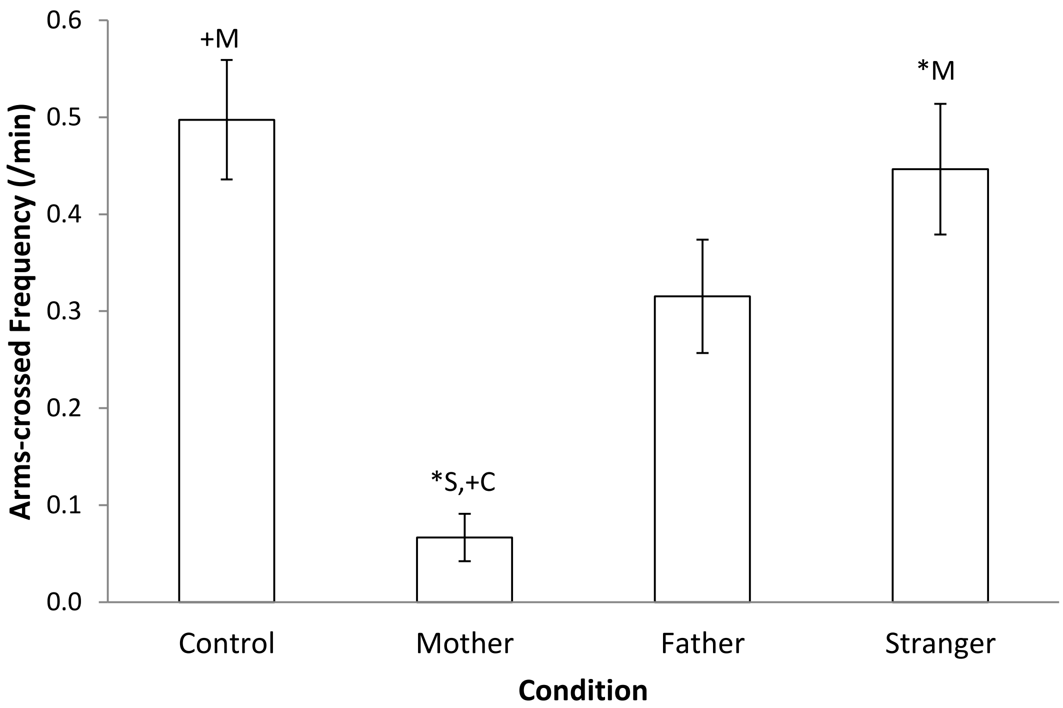

Figure 3.112. Average 'Arm-crossed' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

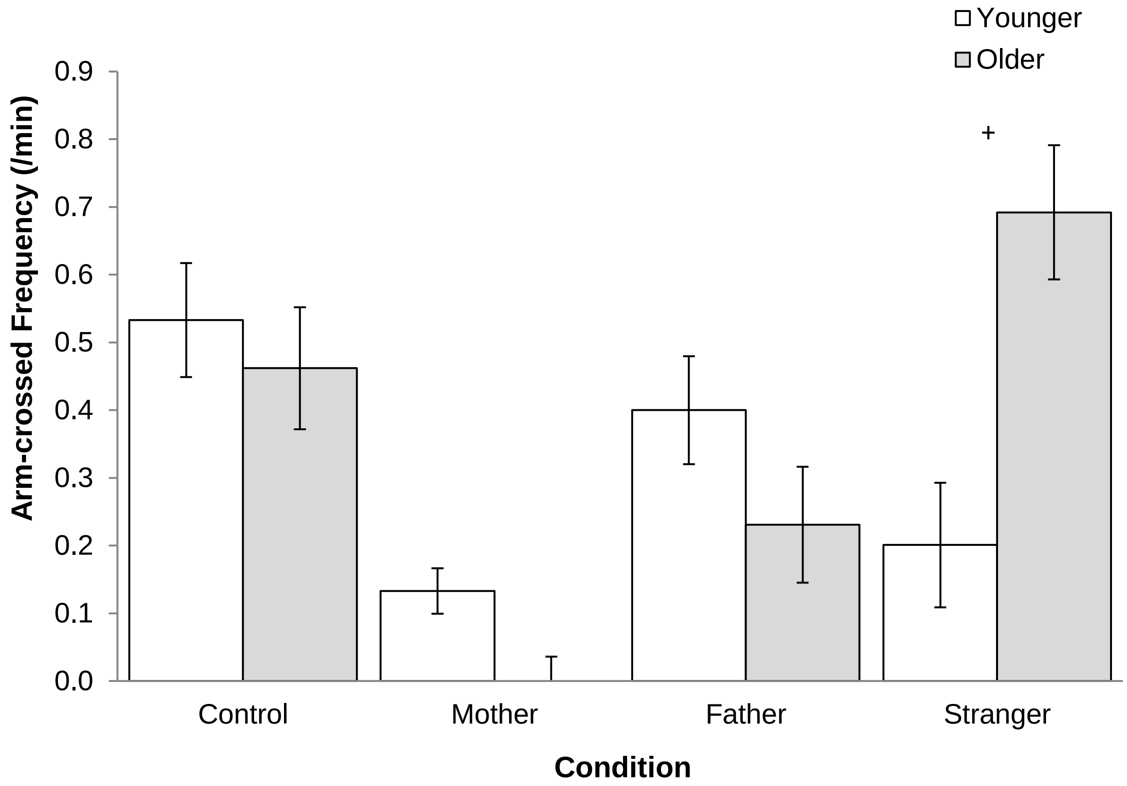

Figure 3.113. Average ‘Arms-crossed’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

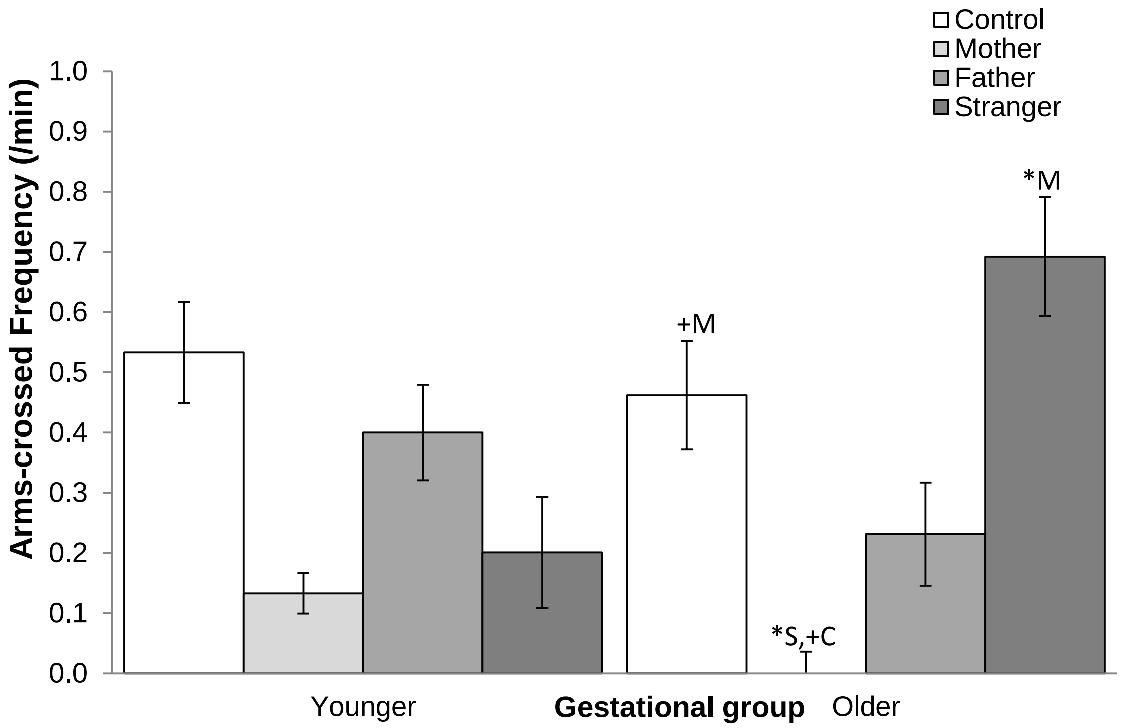

Figure 3.114. Average ‘Arms-crossed’ frequency (in minutes) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: 'Arms-crossed' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the durations of 'Arms-crossed' behaviour. Results showed a marginally significant main effect of Condition F (3, 78) = 2.33, p = .081, η_p^2 = .08, and a tendency for an interaction between Condition and GA, F (3, 78) = 2.35, p = .079, η_p^2 = .08, however no significant main effect of GA F (1, 26) = 1.93, p = .176, η_p^2 = .07. In support of this polynomial contrasts of the Condition main effect showed a significant quadratic trend for Condition F (1, 26) = 4.44, p = .045, η_p^2 = .15, as well as a tendency for a quadratic trend of the interaction of Condition and GA F (1, 26) = 3.58, p = .070, η_p^2 = .16. Overall there is a decrease from 'Control' (M = 28.38) to 'Mother' (M = 6.67). 'Father' (M = 18.26) has a somewhat higher mean which is followed by an increase in the 'Stranger' condition (M = 25.71), producing the quadratic trend.

Post-hoc pairwise comparison of the main effect of Condition revealed no further effects (see Figure 3.115).

Post-hoc pairwise comparison of the interaction revealed a significant difference in the 'Stranger' condition, with older fetuses (M = 42.79) displaying an increased duration of 'Arms-crossed' compared to younger fetuses (M = 8.62, p = .023). Older fetuses showed differences between 'Control' and 'Mother', with a tendency for longer 'Arms-crossed' in 'Control' (M = 35.63) compared to mother's touch (M = 0.00, p = .056). A significant difference was found for older fetuses between 'Mother' and 'Stranger' conditions, with longer 'Arms-crossed' in 'Stranger' (M = 42.79) compared to 'Mother' (M = 0.00, p = .017) (see Figures 3.116 and 3.117). No further effects were found. The means and standard errors can be examined in Table 3.86.

Table 3.86. Means and standard errors (SE) of fetuses 'Arms-crossed' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	14.13	5.51	25.38	5.92		
Control	21.23	10.89	35.63	11.69	28.38	7.99
Mother	13.33	6.67	0.00	7.16	6.67	4.89
Father	13.44	9.60	23.08	10.31	18.26	7.04
Stranger	8.62	9.63	42.79	10.35	25.71	7.07

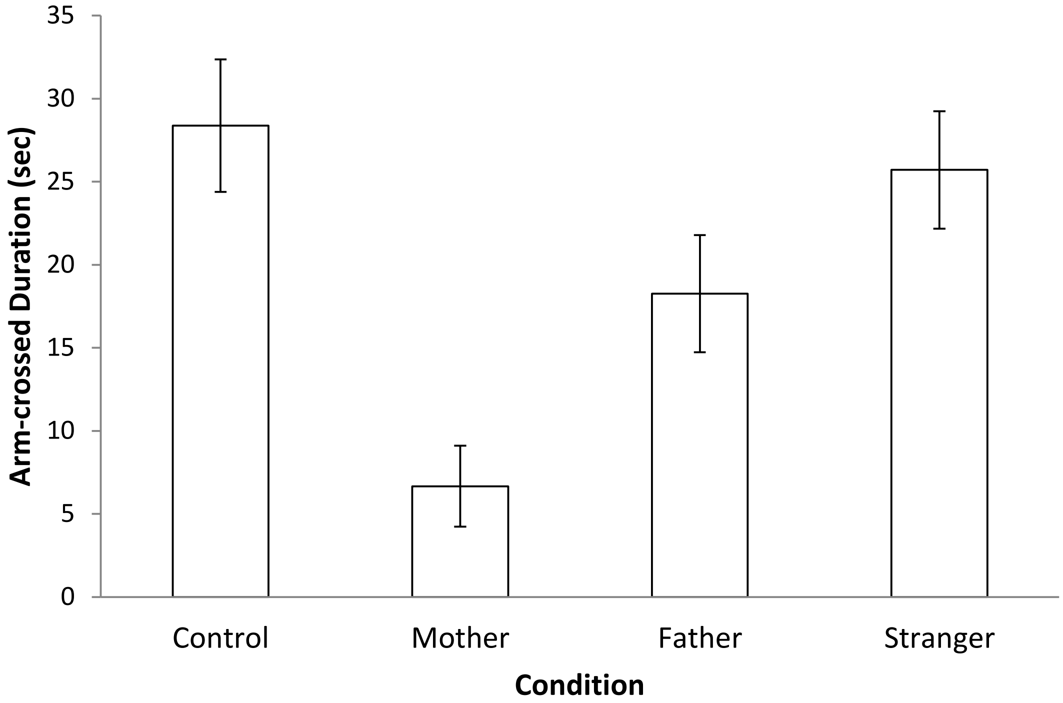

Figure 3.115. Average 'Arms-crossed' duration (in seconds) including standard errors for each condition.

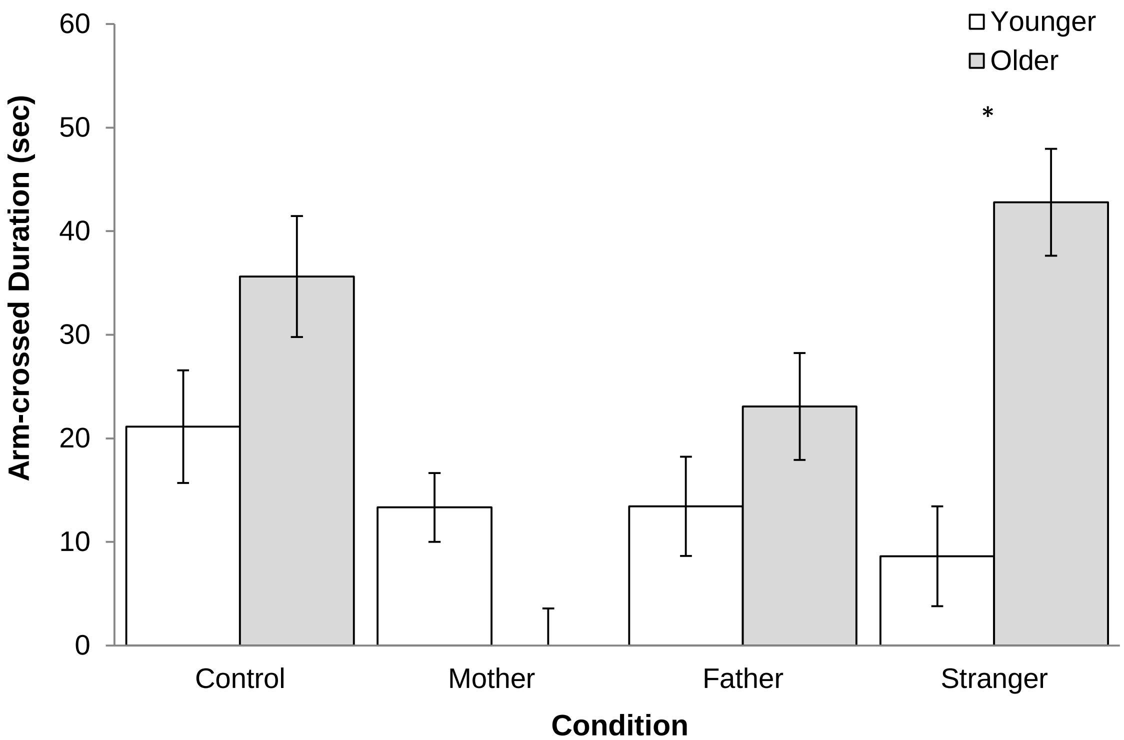

Figure 3.116. Average ‘Arms-crossed’ duration (in seconds) including standard errors for each condition (*< .05).

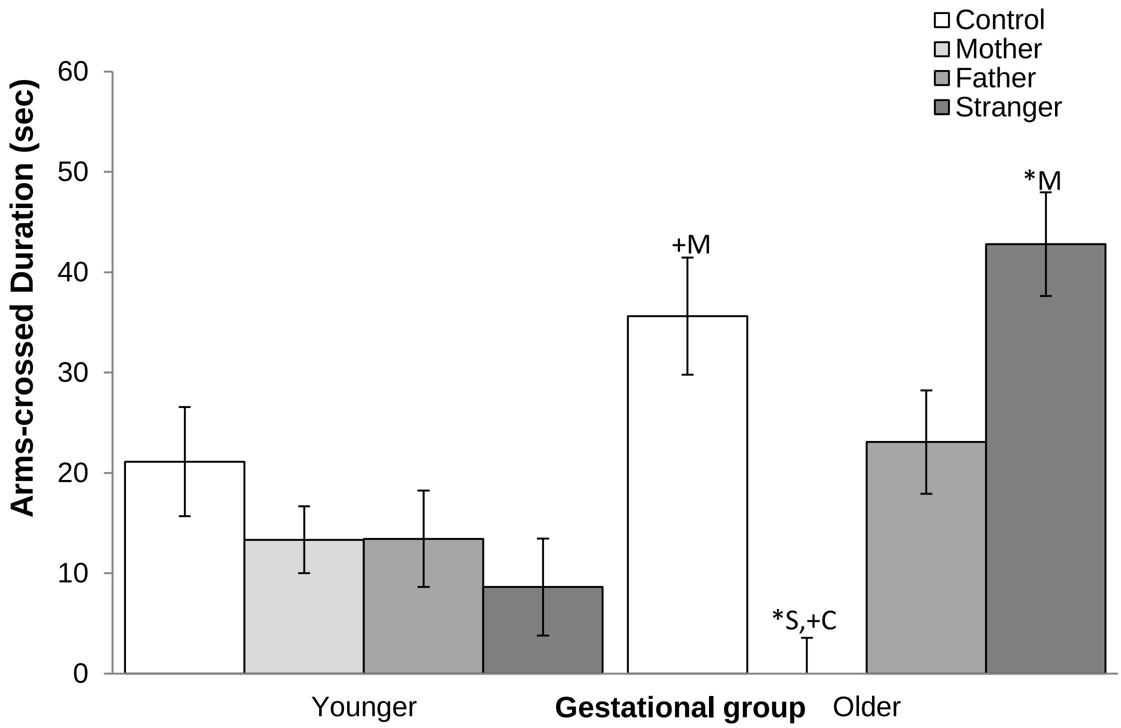

Figure 3.117. Average ‘Arms-crossed’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: 'Mouth movement' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the durations of 'Mouth movements'. Results showed a tendency for an interaction between Condition and GA, F (2.21, 57.45) = 2.50, p = .086, η_p^2 = .09, however no main effect of Condition F (2.21, 57.45) = 0.97, p = .393, η_p^2 = .04, or a significant main effect of GA F (1, 26) = 0.18, p = .671, η_p^2 < .01, were found. In support of this polynomial contrasts of the interaction of Condition and GA show a significant linear trend F (1, 26) = 4.55, p = .043, η_p^2 = .15, as well as a tendency for a cubic trend F (1, 26) = 4.66, p = .040, η_p^2 = .15.

Post-hoc pairwise comparison of the interaction of Condition and GA revealed no further effects (see Figure 3.118 and 3.119). No further effects were found. The means and standard errors can be examined in Table 3.87.

Table 3.87. Means and standard errors (SE) of fetuses 'Mouth movement' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	10.49	3.87	8.05	4.16		
Control	7.99	7.26	15.12	7.80	11.56	5.33
Mother	10.96	3.97	1.67	4.27	6.32	2.92
Father	3.63	4.51	9.58	4.95	6.60	3.38
Stranger	19.36	5.65	5.83	6.07	12.60	4.15

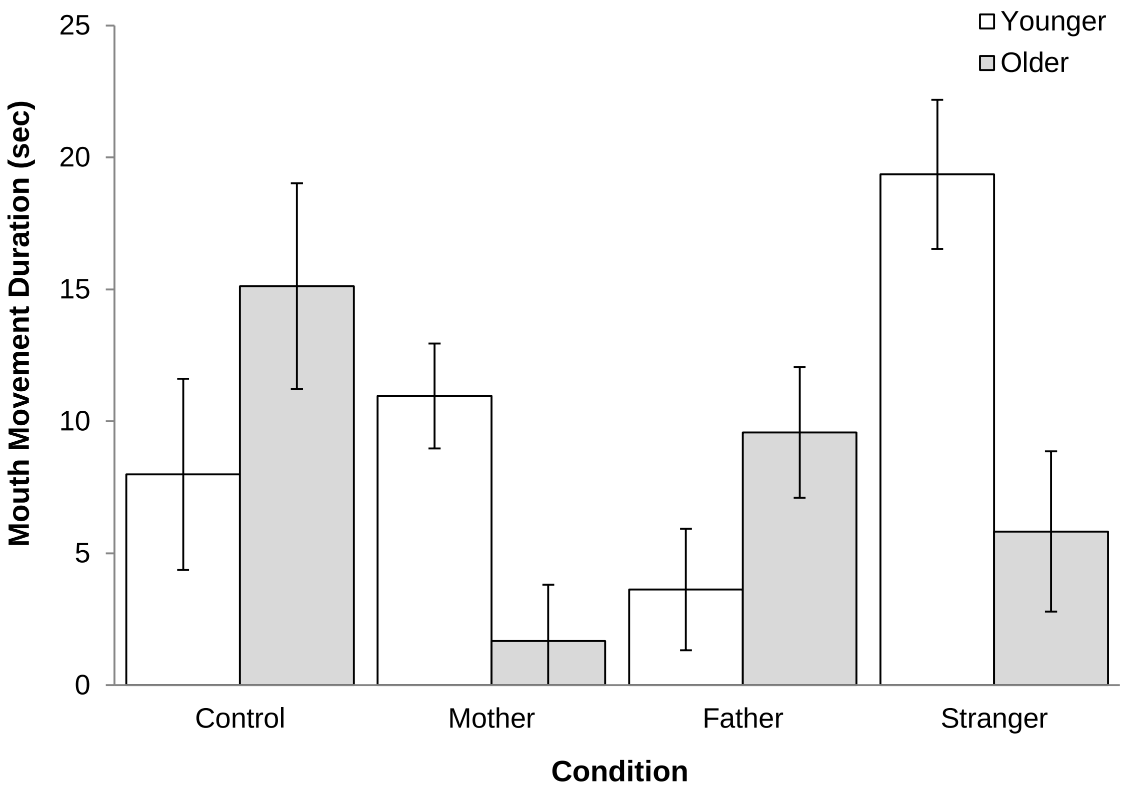

Figure 3.118. Average 'Mouth movement' duration (in seconds) including standard errors for each condition.

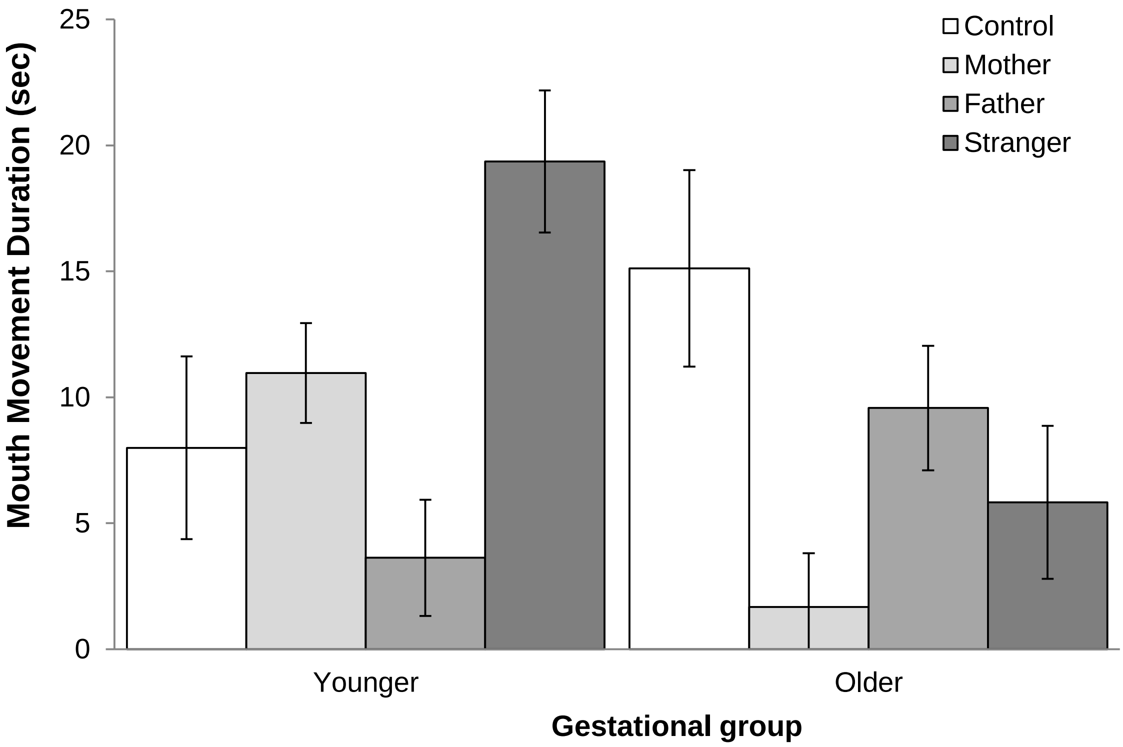

Figure 3.118. Average 'Mouth movement' duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses).

60-120s Interval analysis combined

Repeated-measures ANOVA Condition: 'Self-touch' Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in 'Self-touch' duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (3, 81) = 4.55, p = .005, η_p^2 = .14. Examination of the means suggests that fetuses altered 'Self-touch' duration between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 7.78, p = .010, η_p^2 = .22, and a marginally significant cubic trend F (1, 27) = 4.03, p = .055, η_p^2 = .13, of Condition. Overall, there is a decrease produced by the means from 'Control' (M = 8.13), to 'Mother' (M = 4.77), followed by an increase to 'Father' (M = 7.04), and 'Stranger' (M = 7.83) producing the quadratic and cubic trend.

Post-hoc pairwise comparison revealed a significant difference between 'Mother' and 'Control' conditions, with longer 'Self-touch' duration during 'Control' compared to 'Mother' implying that the fetus touched itself longer during 'Control' (M = 8.13) compared to 'Mother' (M = 4.77, p = .009). A marginally significant difference was found between 'Mother' and 'Stranger', with fetuses touching their own body longer during 'Stranger' (M = 7.04) compared to 'Mother' (M = 4.77, p = .060) (see Figure 3.119). No other effects were found. The means and standard errors can be examined in Table 3.88.

Table 3.88. Means and standard errors (SE) on the duration of fetuses 'Self-touch' across conditions.

	Control	Mother	Father	Stranger
Mean	8.13	4.77	7.04	7.83
SE	0.58	0.85	0.81	0.64

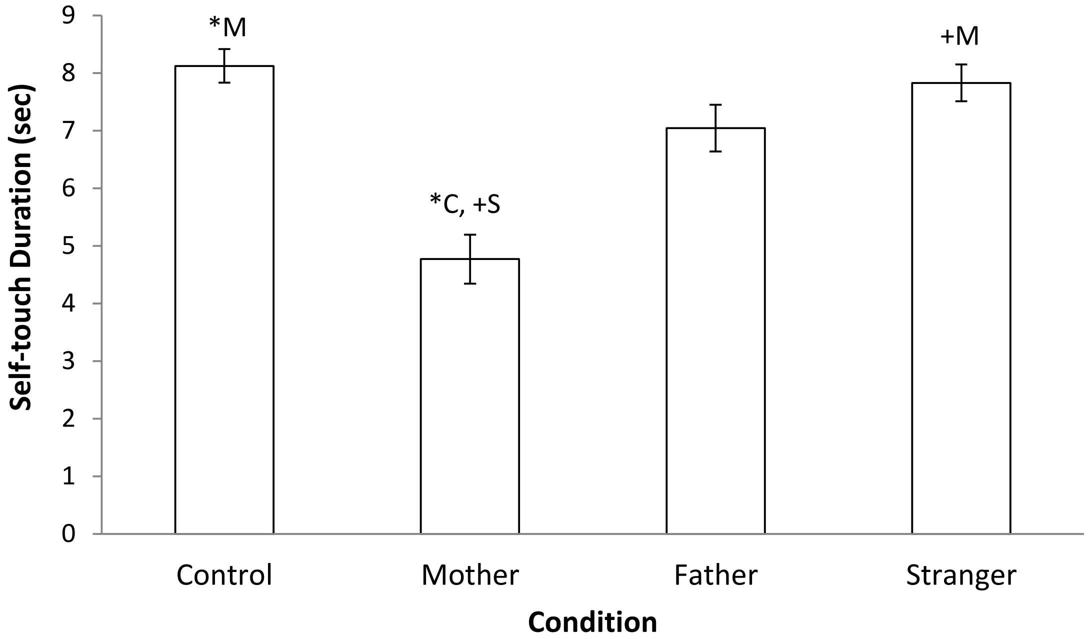

Figure 3.119. Average 'Self-touch' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Repeated-measures ANOVA Condition: 'Inactivity/Resting' Frequency

A repeated-measures ANOVA, using Huynh-Feldt correction, was conducted to assess whether there are differences in 'Inactivity/Resting' frequency between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (2.11, 56.84) = 3.70, p = .029, η_p^2 = .12. Examination of the means suggests that fetuses altered 'Inactivity/Resting' frequency between Conditions. Polynomial contrasts indicated, in support of this, a significant cubic trend, F (1, 27) = 6.22, p = .019, η_p^2 = .19, and a marginally significant linear trend F (1, 27) = 3.51, p = .072, η_p^2

= .12, of Condition. Overall, there is a decrease produced by the means from ‘Control’ (M = 0.64), to ‘Mother’ (M = 0.21), followed by an increase to ‘Father’ (M = 0.68), and ‘Stranger’ (M = 0.79) producing the cubic and linear trends.

Post-hoc pairwise comparison revealed a significant difference between ‘Control’ and ‘Mother’ conditions, with a higher ‘Inactivity/Resting’ frequency during ‘Control’ compared to ‘Mother’ implying that the fetus was more active when the mother (M = 0.21) touched compared to ‘Control’ (M = 0.64, p = .047). A significant difference was found between ‘Mother’ and ‘Father’, with an increased ‘Inactivity/Resting’ for ‘Father’ (M = 0.68) compared to ‘Mother’, again implying that the fetus was more active during maternal touch (M = 0.21, p = .016). A tendency was found between ‘Mother’ and ‘Stranger’, with increased fetal activity during ‘Mother’ (M = 0.21) and an increased ‘Inactivity/Resting’ during ‘Stranger’ (M = 0.78, p = .077) (see Figure 3.120). No other effects were found. The means and standard errors can be examined in Table 3.89.

Table 3.89. Means and standard errors (SE) on the frequency of fetuses ‘Inactivity/Resting’ across conditions.

	Control	Mother	Father	Stranger
Mean	0.64	0.21	0.68	0.79
SE	0.15	0.09	0.16	0.21

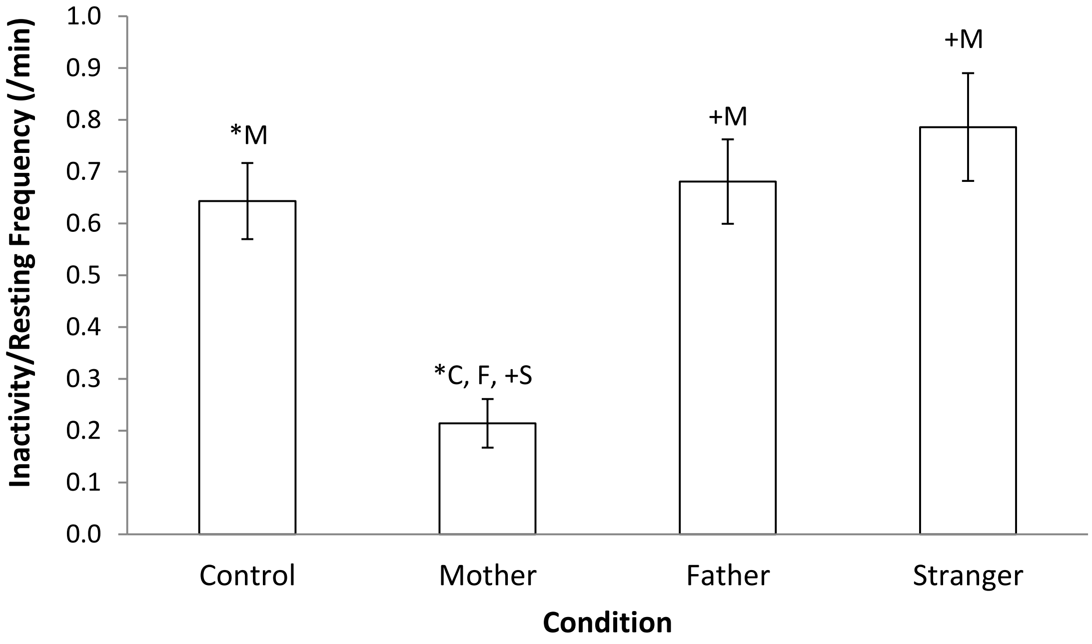

Figure 3.120. Average 'Inactivity/Resting' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Repeated-measures ANOVA Condition: 'Inactivity/Resting' Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in 'Inactivity/Resting' duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a marginally significant main effect of Condition F (3, 81) = 2.43, p = .071, η_p^2 = .08. Examination of the means suggests that fetuses altered 'Inactivity/Resting' duration between Conditions. Polynomial contrasts indicated, in support of this, a significant cubic trend, F (1, 27) = 5.80, p = .023, η_p^2 = .18. Overall, there is a decrease produced by the means from 'Control' (M = 3.87), to 'Mother' (M = 1.73), followed by an increase to 'Father' (M = 4.62), and a slight decrease to 'Stranger' (M = 4.18) producing the cubic trend.

Post-hoc pairwise comparison revealed a marginally significant difference between 'Mother' and 'Father' conditions, with a longer 'Inactivity/Resting' duration during father's touch compared to 'Mother' implying that the fetus was more active when the mother (M = 1.73) touched compared to the father (M = 4.62, p = .096) (see Figure 3.121). No further effects were found. The means and standard errors can be examined in Table 3.90.

Table 3.90. Means and standard errors (SE) on the duration of fetuses 'Inactivity/Resting' across conditions.

	Control	Mother	Father	Stranger
Mean	3.87	1.73	4.62	4.18
SE	1.00	0.72	1.00	0.90

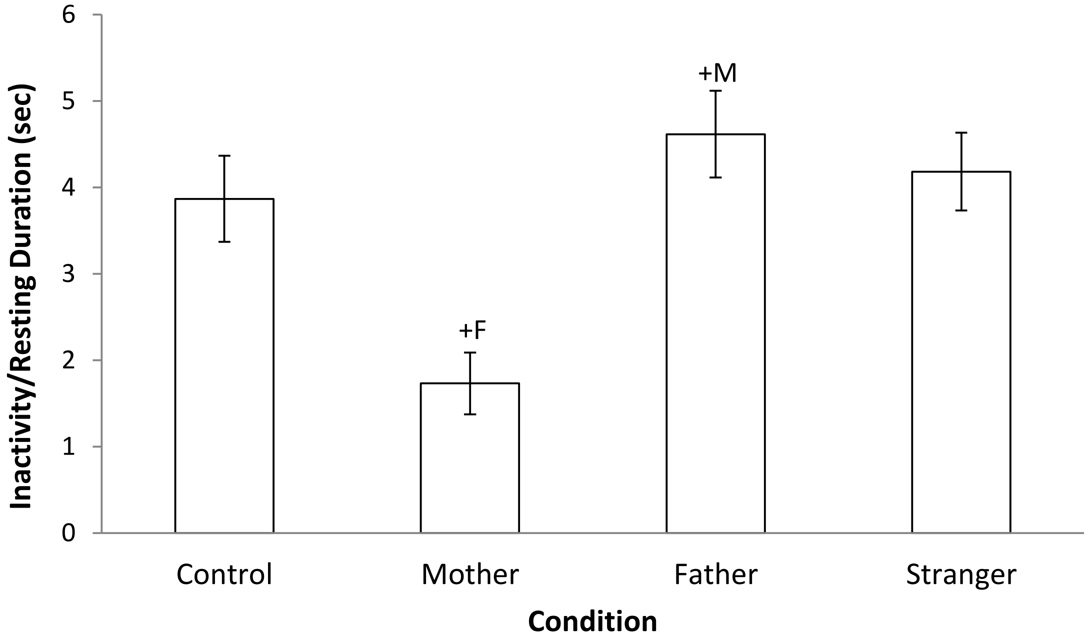

Figure 3.121. Average 'Inactivity/Resting' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Self-touch' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Self-touch'. Results showed a significant of main effect of Condition F (3, 78) = 4.61, p = .005, η_p^2 = .15. No significant interaction between Condition and GA, F (3, 78) = 1.23, p = .306, η_p^2 = .05, or main effect of GA F (1, 26) = 0.01, p = .932, η_p^2 < .001, were found. In support of this polynomial contrasts of the main effect of Condition show a significant quadratic trend F (1, 26) = 7.40, p = .011, η_p^2 = .22, and a marginally significant cubic trend F (1, 26) = 4.18, p = .051, η_p^2 = .14. Overall, there is a decrease produced by the means from 'Control' (M = 8.19) to the ‘Mother’ (M = 4.76) followed by an increase to ‘Father’ (M = 7.06) and ‘Stranger’ (M = 7.76) producing quadratic and cubic trends.

Post-hoc pairwise comparison of the main effect of Condition revealed a significant difference between ‘Control’ and ‘Mother’, with longer ‘Self-touch’ durations during ‘Control’ (M = 8.19) compared to ‘Mother’ (M = 4.76, *p* = .008). A marginally significant difference was found between ‘Mother’ and ‘Stranger’, with longer ‘Self-touch’ durations during ‘Stranger’ (M = 7.76) compared to ‘Mother’ (M = 4.76, *p* = .075) (see Figure 3.122). No further effects were found. The means and standard errors can be examined in Table 3.91.

Table 3.91. Means and standard errors (SE) of fetuses ‘Self-touch’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	6.97	0.54	6.91	0.58		
Control	7.33	0.78	9.04	0.84	8.19	0.57
Mother	4.90	1.18	4.62	1.27	4.76	0.87
Father	6.87	1.13	7.24	1.22	7.06	0.83
Stranger	8.80	0.84	6.72	0.91	7.76	0.62

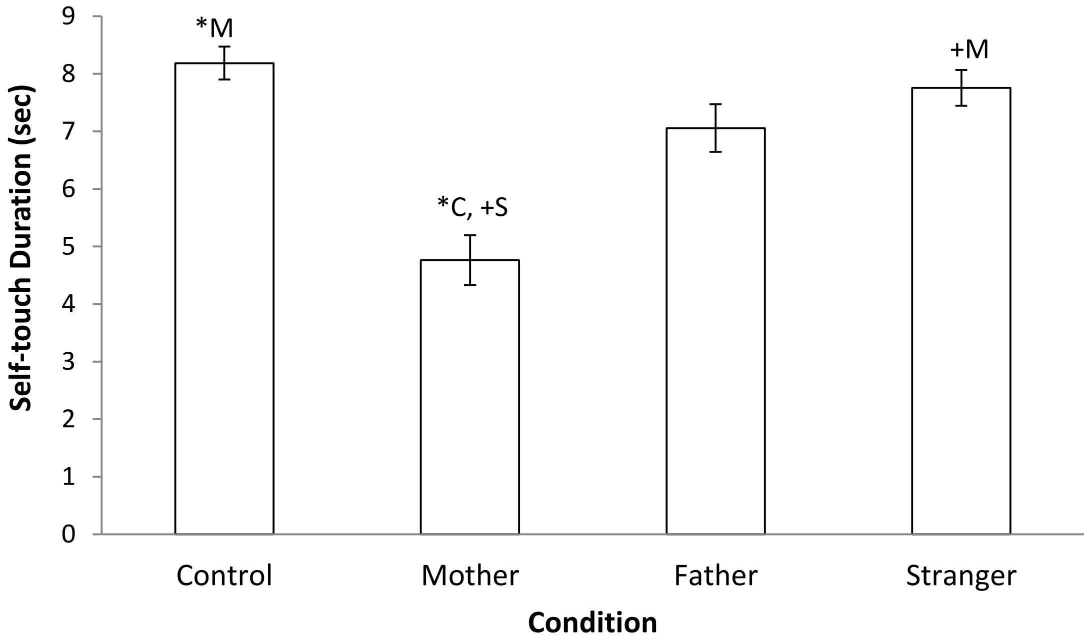

Figure 3.122. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: ‘Inactivity/Resting’ Frequency

A mixed-design ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Inactivity/Resting’. The main effect of Condition indicates a significant difference, F (1.97, 51.15) = 3.65, p = .034, η_p^2 = .12. Neither a main effect of GA F (1, 26) = 0.44, p = .512, η_p^2 = .02, nor an interaction effect F (1.97, 51.15) = 0.64, p = .530, η_p^2 = .02, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 5.86, p = .023, η_p^2 = .18, and marginally significant linear trend F (1, 26) = 3.60, p = .069, η_p^2 = .12, of Condition, indicating a decrease from ‘Control’ (M = 0.64) to ‘Mother’ (M = 0.21), followed by an increase to ‘Father’ (M = 0.67), and ‘Stranger’ (M = 0.79).

Post-hoc pairwise comparison of the Condition main effect showed a significant difference between ‘Mother’ and ‘Father’ with a higher frequency of ‘Inactivity/Resting’ in ‘Father’ (M = 0.67) compared to ‘Mother’ (M = 0.21, p = .020). Marginally significant results were found between ‘Control’ and ‘Mother’, with higher frequencies of ‘Inactivity/Resting’ during ‘Control’ (M = 0.64) compared to ‘Mother’ (M = 0.21, *p* = .058). Furthermore, marginally significant differences were found between ‘Mother’ and ‘Stranger’, with higher frequencies of ‘Inactivity/Resting’ during ‘Stranger’ (M = 0.79) compared to ‘Mother’ (M = 0.21, *p* = .080) (see Figure 3.123). No further effects were found. The means and standard errors can be examined in Table 3.92.

Table 3.92. Means and standard errors (SE) of fetuses ‘Inactivity/Resting’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.65	0.15	0.50	0.16		
Control	0.73	0.20	0.54	0.22	0.64	0.15
Mother	0.27	0.13	0.15	0.14	0.21	0.10
Father	0.87	0.22	0.47	0.24	0.67	0.16
Stranger	0.74	0.29	0.85	0.31	0.79	0.21

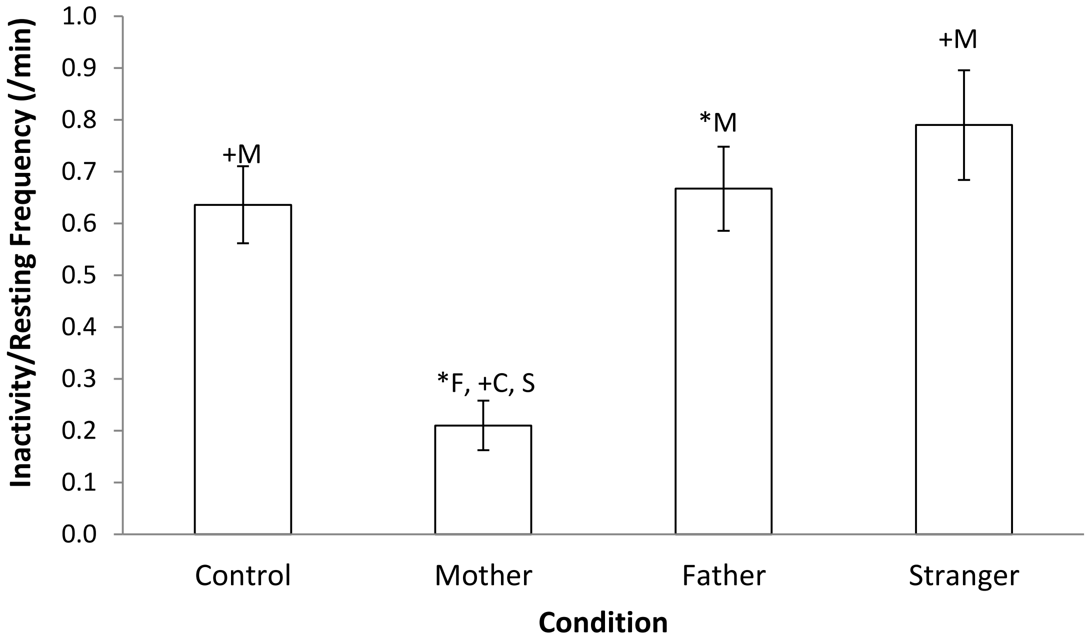

Figure 3.123. Average 'Inactivity/Resting' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

Mixed-design ANOVA Condition*GA: 'Inactivity/Resting' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Inactivity/Resting'. The main effect of Condition indicates a marginally significant difference, F (3, 78) = 2.52, p = .064, η_p^2 = .09. Neither a main effect of GA F (1, 26) = 0.54, p = .468, η_p^2 = .02, nor an interaction effect F (3, 78) = 0.91, p = .439, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 5.53, p = .027, η_p^2 = .18, of Condition, indicating a decrease from 'Control' (M = 3.90) to 'Mother' (M = 1.71), followed by an increase to 'Father' (M = 4.62) and 'Stranger' (M = 4.29).

The post-hoc analysis did not reveal any further results (see Figure 3.124). No further effects were found. The means and standard errors can be examined in Table 3.93.

Table 3.93. Means and standard errors (SE) of fetuses 'Inactivity/Resting' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	3.39	0.80	3.95	0.85		
Control	3.53	1.36	3.90	1.46	3.72	1.00
Mother	2.00	0.98	1.36	1.05	1.68	0.72
Father	4.90	1.41	4.62	1.51	4.76	1.03
Stranger	3.13	1.23	5.91	1.33	4.52	0.91

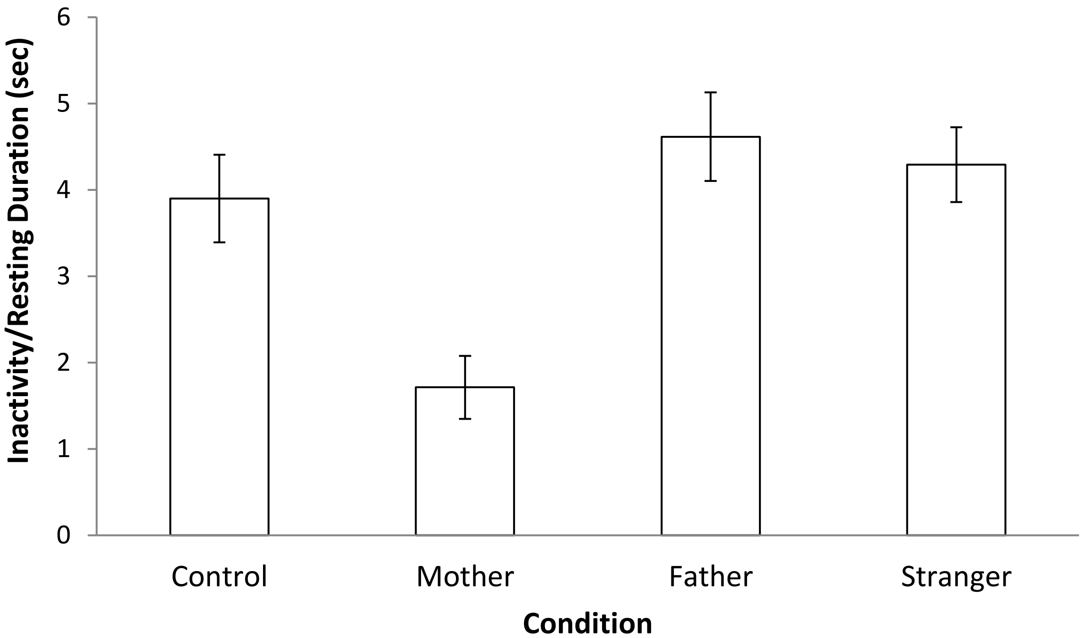

Figure 3.124. Average 'Inactivity/Resting' duration (in seconds) including standard errors for each condition.

90-120s Interval

Repeated-measures ANOVA Condition: ‘Body touch’ Frequency

A repeated-measures ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of ‘Body touch’. Results showed a tendency between Conditions F (3, 81) = 2.29, p = .084, η_p^2 = .08. Examination of the means suggests that fetuses tend to alter ‘Body touch’ frequency depending on Condition. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 6.51, p = .018, η_p^2 = .19. Overall, there is a decrease produced by the means from ‘Control’ (M = 0.71) to ‘Mother’ (M = 0.36) and ‘Father’ (M = 0.36). However, ‘Stranger’ (M = 0.93) has a somewhat higher mean, producing the quadratic trend.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.125). The means and standard errors can be examined in Table 3.94.

Table 3.94. Means and standard errors (SE) on the frequency of fetuses ‘Body touch’ across conditions.

	Control	Mother	Father	Stranger
Mean	0.71	0.36	0.36	0.93
SE	0.26	0.15	0.15	0.26

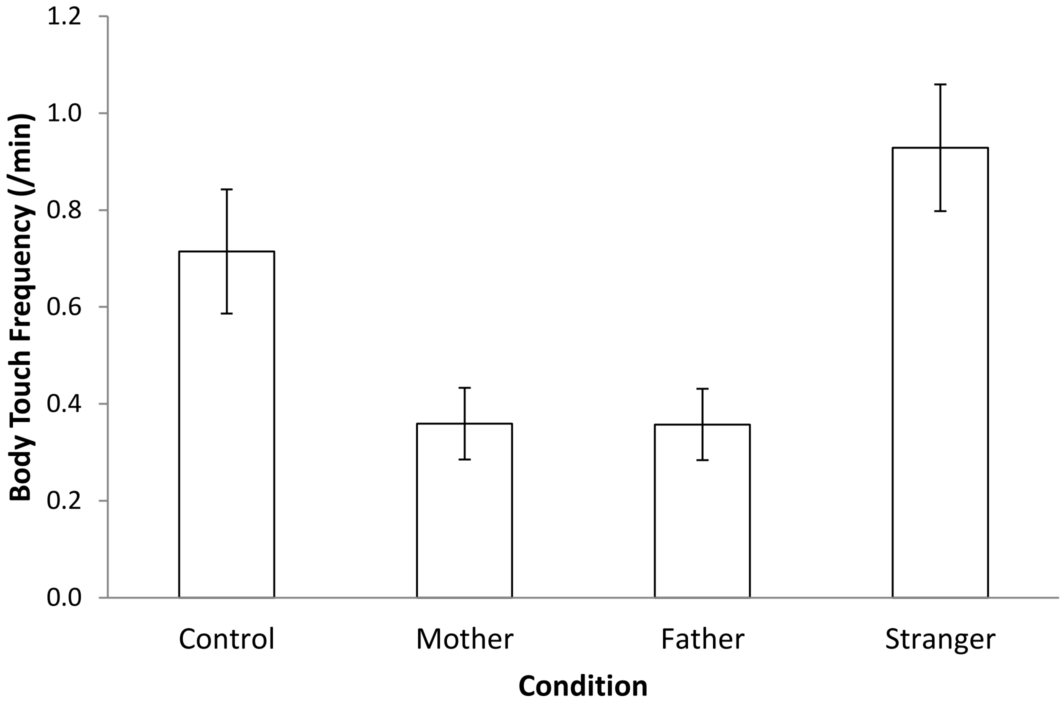

Figure 3.125. Average ‘Body touch’ frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: ‘Arms-crossed’ Frequency

A repeated-measures ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of ‘Arm-crossed’ behaviour. Results showed a tendency between Conditions F (3, 81) = 2.44, p = .071, η_p^2 = .08. Examination of the means suggests that fetuses tend to alter arm-cross frequency depending on Condition. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 6.09, p = .020, η_p^2 = .18. Overall, there is a decrease produced by the means from ‘Control’ (M = 0.71) to ‘Mother’ (M = 0.14). Means increase from ‘Mother’ to ‘Father’ (M = 0.43) and for ‘Stranger’ (M = 0.72) producing the quadratic trend.

Post-hoc pairwise comparison revealed a tendency between ‘Control’ and ‘Mother’ with more ‘Arms-crossed’ in ‘Control’ (M = 0.71) compared to ‘Mother’ (M = 0.14, p = .052) (see Figure 3.126). No further effects were found. The means and standard errors can be examined in Table 3.95.

Table 3.95. Means and standard errors (SE) on the frequency of fetuses 'Arms-crossed' across conditions.

	Control	Mother	Father	Stranger
Mean	0.71	0.14	0.43	0.72
SE	0.18	0.10	0.19	0.24

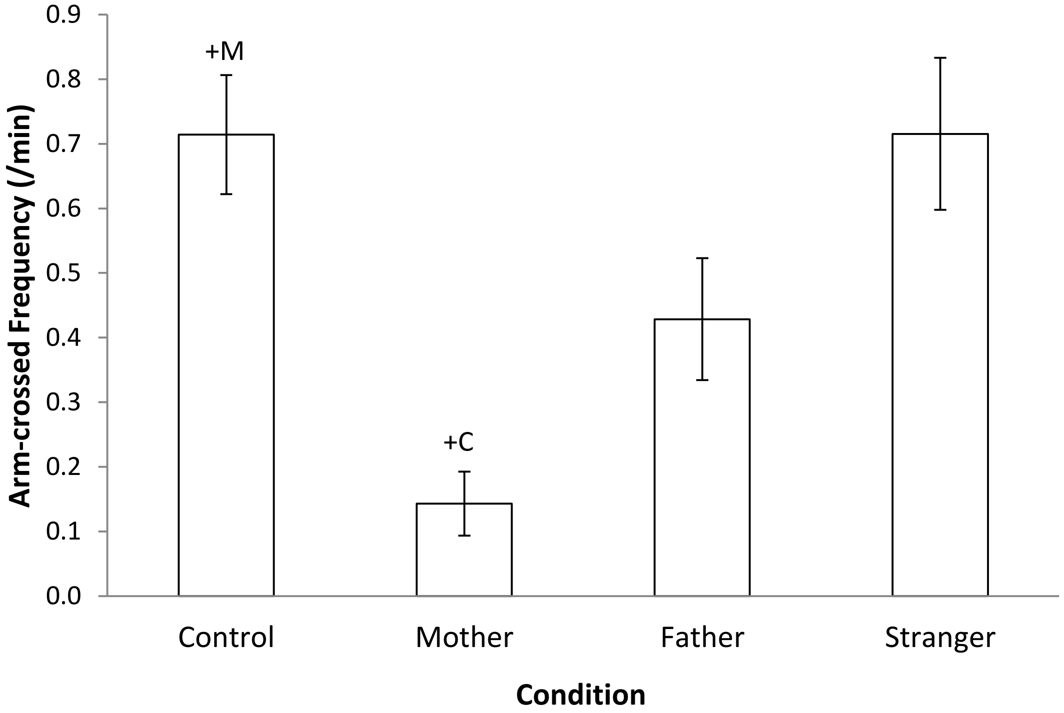

Figure 3.126. Average 'Arms-crossed' frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: 'Hand movement' Duration

A repeated-measures ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of 'Hand movement'. Results showed a tendency between Conditions F (1.29, 34.69) = 2.92, p = .087, η_p^2 = .10. Examination of the means suggests that fetuses tend to alter hand movement duration depending on Condition. Polynomial contrasts indicated, in support of this, a significant cubic trend, F (1, 27) = 3.67, p = .066, η_p^2 = .12. Overall, there is an increase produced by the means from 'Control' (M = 2.31) to 'Mother' (M =

12.73). ‘Father’ (M = 1.79) has a somewhat lower mean and is followed by an increase to ‘Stranger’ (M = 3.75) producing the cubic trend.

The post-hoc pairwise comparison revealed no further effects (see Figure 3.127). No further effects were found. The means and standard errors can be examined in Table 3.96.

Table 3.96. Means and standard errors (SE) on the frequency of fetuses ‘Hand movements’ across conditions.

	Control	Mother	Father	Stranger
Mean	2.31	12.73	1.79	3.75
SE	0.85	5.92	0.94	1.86

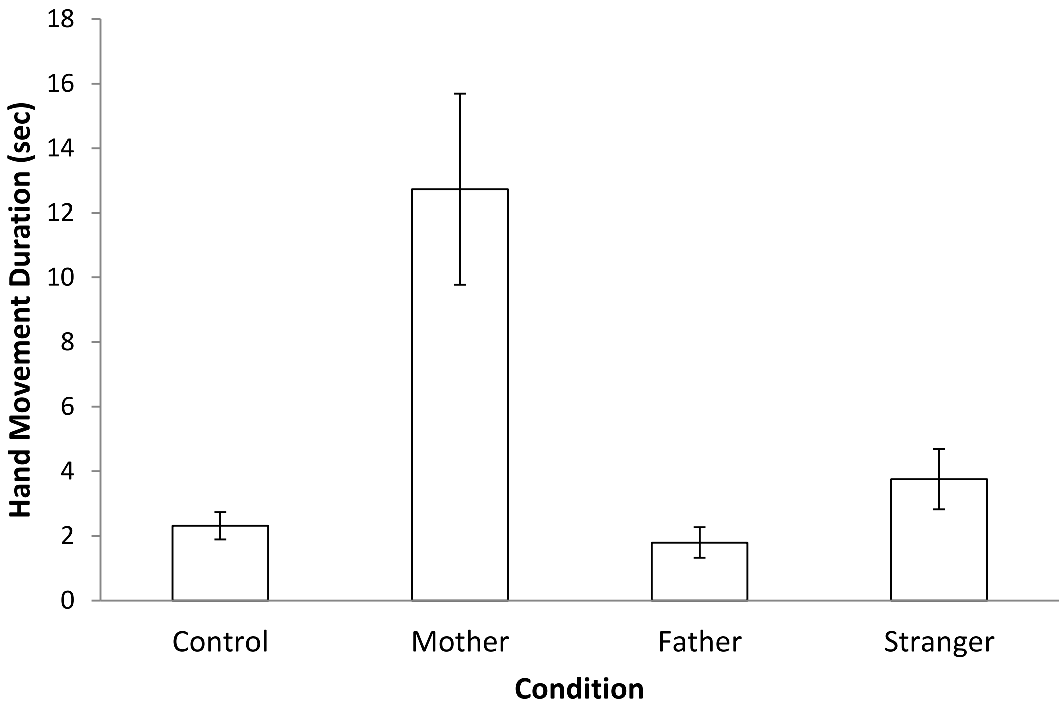

Figure 3.127. Average ‘Hand movement’ duration (in seconds) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: 'Body touch' Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of 'Body touch'. Results showed a tendency of main effect of Condition *F* (3, 78) = 2.58, *p* = .059, η_p^2 = .09. No significant interaction between Condition and GA, *F* (3, 78) = 2.09, *p* = .109, η_p^2 = .07, or a significant main effect of GA *F* (1, 26) = 0.93, *p* = .925, η_p^2 = .03, were found. In support of this polynomial contrasts of the interaction showed a significant quadratic trend for Condition *F* (1, 26) = 7.01, *p* = .014, η_p^2 = .21. Overall there is a decrease from 'Control' (M = 0.72) to 'Mother' (M = 0.35). 'Father' (M = 0.37) has a somewhat higher mean which is followed by a further increase in the 'Stranger' condition (M = 0.96), producing the quadratic trend.

Post-hoc pairwise comparison of the main effect of Condition revealed no further effects (see Figure 3.128). No further effects were found. The means and standard errors can be examined in Table 3.97.

Table 3.97. Means and standard errors (SE) of fetuses 'Body touch' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.47	0.19	0.73	0.20		
Control	0.67	0.36	0.77	0.38	0.72	0.26
Mother	0.54	0.20	0.15	0.22	0.35	0.15
Father	0.13	0.20	0.62	0.21	0.37	0.14
Stranger	0.53	0.35	1.39	0.37	0.96	0.25

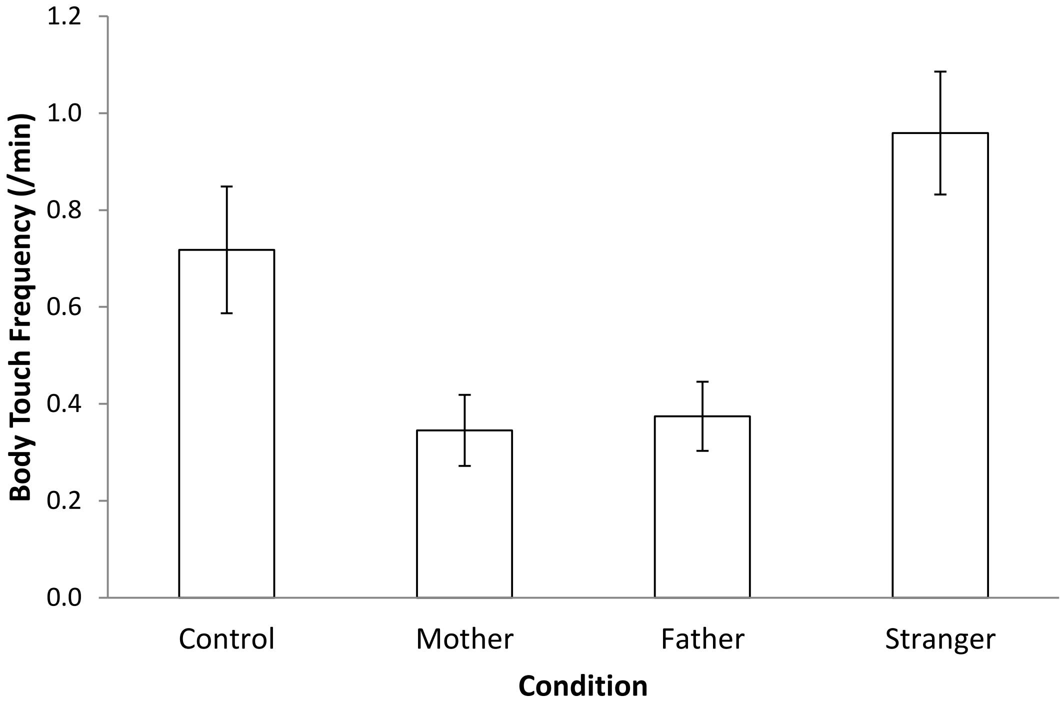

Figure 3.128. Average 'Body touch' frequency (per minute) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: 'Arms-crossed' Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequencies of 'Arms-crossed'. Results showed a significant main effect of Condition F (3, 78) = 2.86, p = .042, η_p^2 = .10, and a tendency for an interaction between Condition and GA, F (3, 78) = 2.33, p = .081, η_p^2 = .08, however no significant main effect of GA F (1, 26) = 2.00, p = .169, η_p^2 = .07. In support of this polynomial contrasts of the Condition main effect showed a significant quadratic trend for Condition F (1, 26) = 8.11, p = .009, η_p^2 = .24, as well as a quadratic trend for the interaction of Condition and GA F (1, 26) = 5.88, p = .023, η_p^2 = .19. Overall there is a decrease from 'Control' (M = 0.73) to 'Mother' (M = 0.13). 'Father' (M = 0.43) has a somewhat higher mean which is followed by an increase in the 'Stranger' condition (M = 0.75), producing the quadratic trend.

Post-hoc pairwise comparison of the main effect of Condition showed a significant difference between 'Control' and 'Mother', with more 'Arms-crossed' during ‘Control’ (M = 0.73) compared to mothers’ touch (M = 0.13, p = .033) (see Figure 3.129).

Post-hoc pairwise comparison of the interaction revealed a significant difference in the ‘Stranger’ condition, with older fetuses (M = 1.23) displaying more ‘Arms-crossed’ compared to younger fetuses (M = 0.27, p = .039). Older fetuses showed significant differences between ‘Control’ and ‘Mother’, with more ‘Arms-crossed’ in ‘Control’ (M = 0.92) compared to mother’s touch (M = 0.00, p = .021). A significant difference was found for older fetuses between ‘Mother’ and ‘Stranger’ conditions, with more ‘Arms-crossed’ in ‘Stranger’ (M = 1.23) compared to ‘Mother’ (M = 0.00, p = .013) (see Figures 3.130 and 3.131). No further effects were found. The means and standard errors can be examined in Table 3.98.

Table 3.98. Means and standard errors (SE) of fetuses ‘Arms-crossed’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.37	0.14	0.65	0.15		
Control	0.53	0.25	0.92	0.27	0.73	0.19
Mother	0.27	0.13	0.00	0.14	0.13	0.10
Father	0.40	0.26	0.46	0.28	0.43	0.19
Stranger	0.27	0.30	1.23	0.32	0.75	0.22

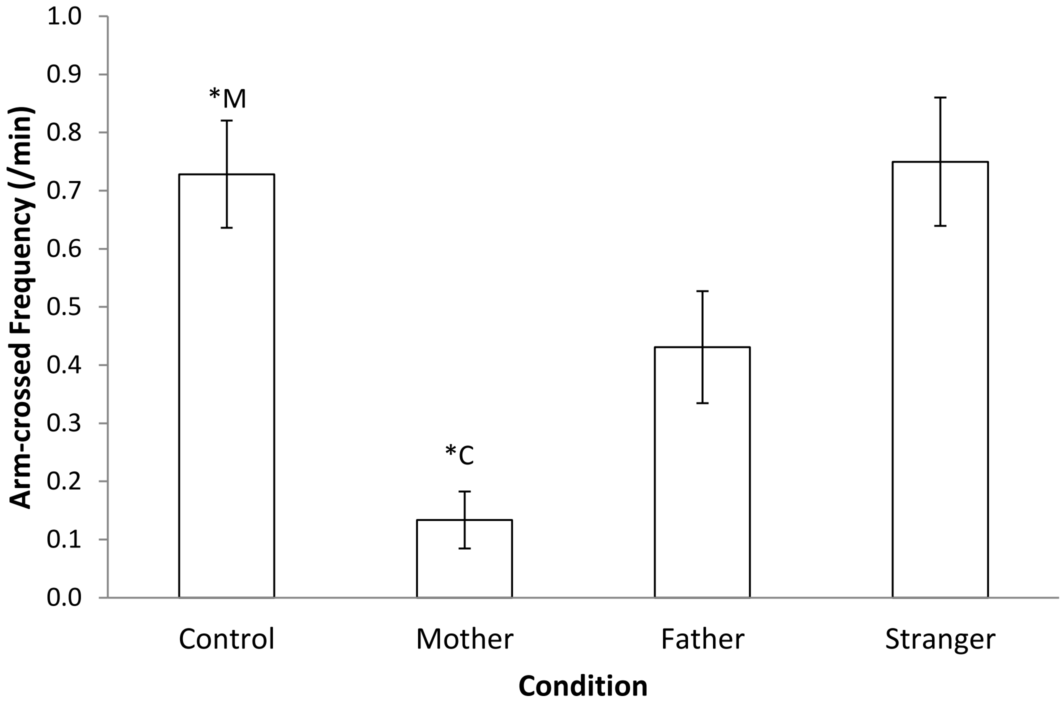

Figure 3.129. Average 'Arms-crossed' frequency (per minute) including standard errors for each condition (*< .05).

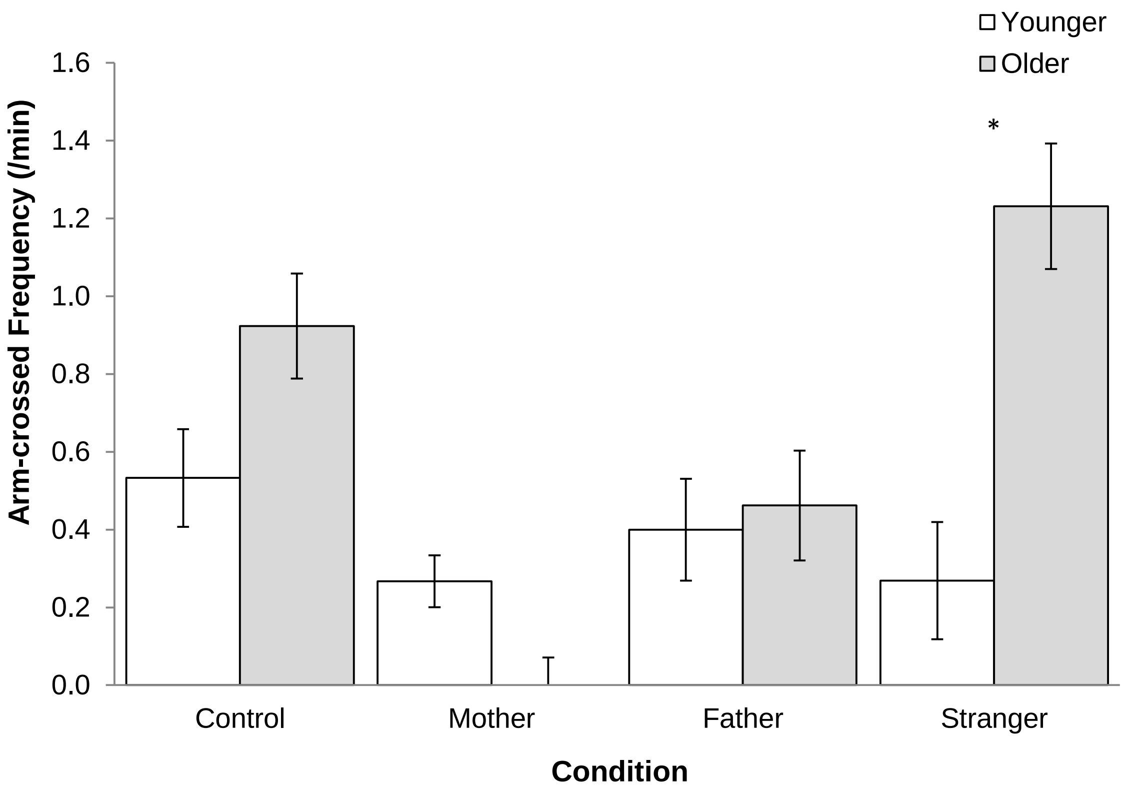

Figure 3.130. Average 'Arms-crossed' frequency (per minute) including standard errors for each condition (*< .05).

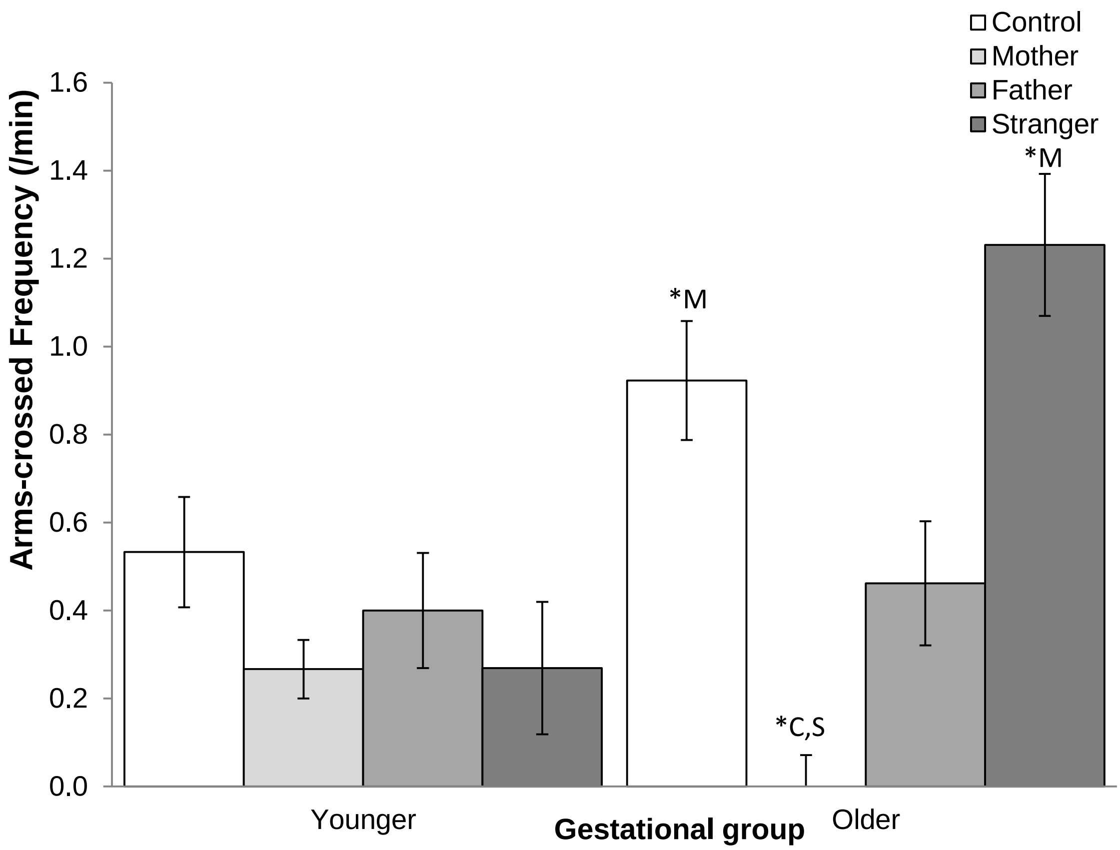

Figure 3.131. Average ‘Arms-crossed’ frequency (in minutes) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

Mixed-design ANOVA Condition*GA: ‘Arms-crossed’ Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the durations of ‘Arms-crossed’. Results showed a tendency of main effect of Condition *F* (3, 78) = 2.35, *p* = .078, η_p^2 = .08, and a tendency for an interaction between Condition and GA, *F* (3, 78) = 2.53, *p* = .064, η_p^2 = .09, however no significant main effect of GA *F* (1, 26) = 2.71, *p* = .112, η_p^2 = .09. In support of this polynomial contrasts of the Condition main effect showed a significant quadratic trend for Condition *F* (1, 26) = 4.67, *p* = .040, η_p^2 = .15, as well as a significant quadratic trend of the interaction of Condition and GA *F* (1, 26) = 4.52, *p* = .043, η_p^2 = .15. Overall there is a decrease from ‘Control’ (M = 30.30) to ‘Mother’ (M = 6.67). ‘Father’ (M

= 17.59) has a somewhat higher mean which is followed by an increase in the ‘Stranger’ condition (M = 23.56), producing the quadratic trend.

Post-hoc pairwise comparison of the main effect of Condition revealed a tendency between ‘Control’ and ‘Mother’, with increased arm-crossed duration in ‘Control’ (M = 30.30) compared to ‘Mother’ (M = 6.67, p = .087) (see Figure 3.132).

Post-hoc pairwise comparison of the interaction revealed a significant difference in the ‘Stranger’ condition, with older fetuses (M = 41.86) displaying an increased duration of ‘Arms-crossed’ compared to younger fetuses (M = 5.26, p = .011). Older fetuses showed a significant difference between ‘Control’ and ‘Mother’, with longer ‘Arms-crossed’ in ‘Control’ (M = 39.96) compared to mother’s touch (M = 0.00, p = .033). A significant difference was found for older fetuses between ‘Mother’ and ‘Stranger’ conditions, with longer ‘Arms-crossed’ in ‘Stranger’ (M = 41.86) compared to ‘Mother’ (M = 0.00, p = .014) (see Figures 3.133 and 3.134). No further effects were found. The means and standard errors can be examined in Table 3.99.

Table 3.99. Means and standard errors (SE) of fetuses ‘Arms-crossed’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	12.83	5.55	26.23	5.96		
Control	20.65	11.69	39.96	12.56	30.30	8.58
Mother	13.33	6.67	0.00	7.16	6.67	4.89
Father	12.10	9.81	23.08	10.54	17.59	7.20
Stranger	5.26	9.15	41.86	9.82	23.56	6.71

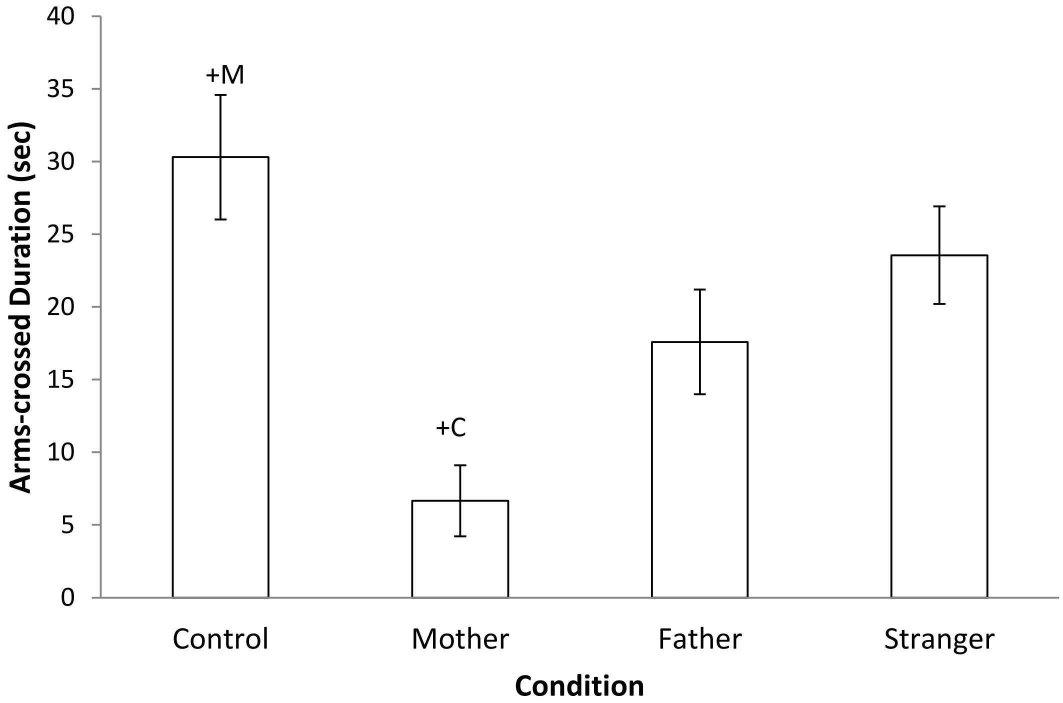

Figure 3.132. Average 'Arms-crossed' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

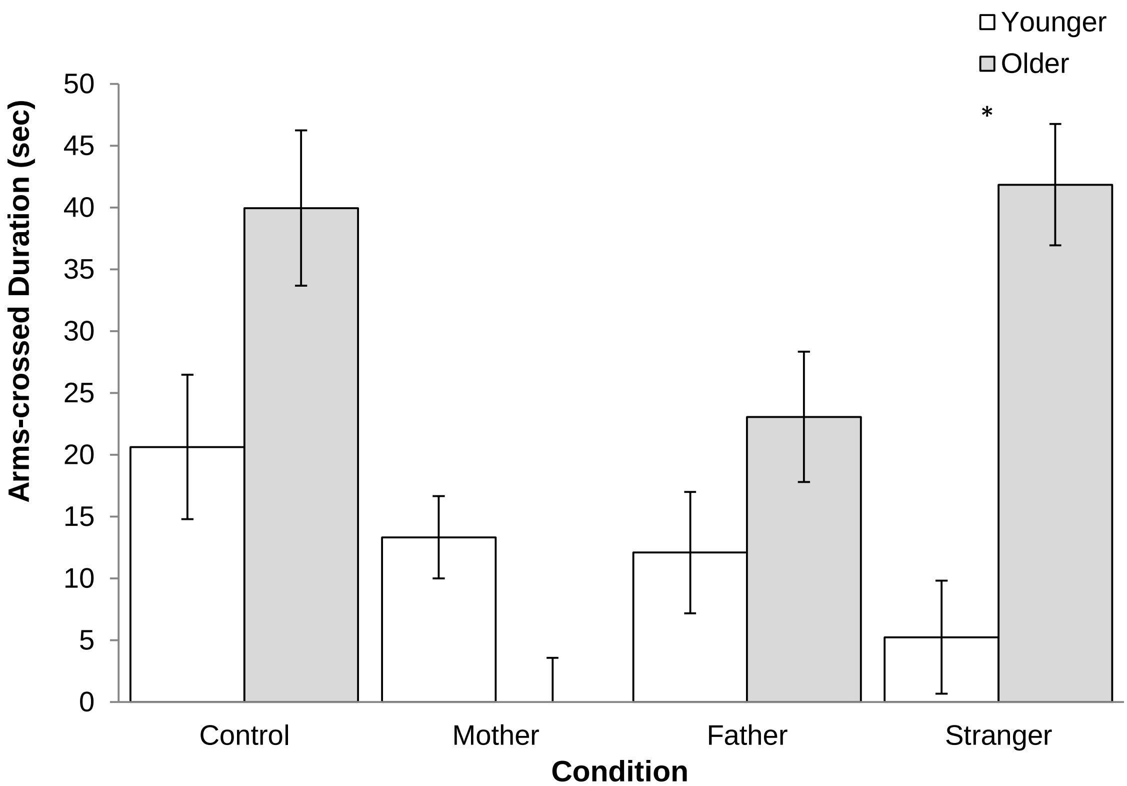

Figure 3.133. Average 'Arms-crossed' duration (in seconds) including standard errors for each condition (*< .05).

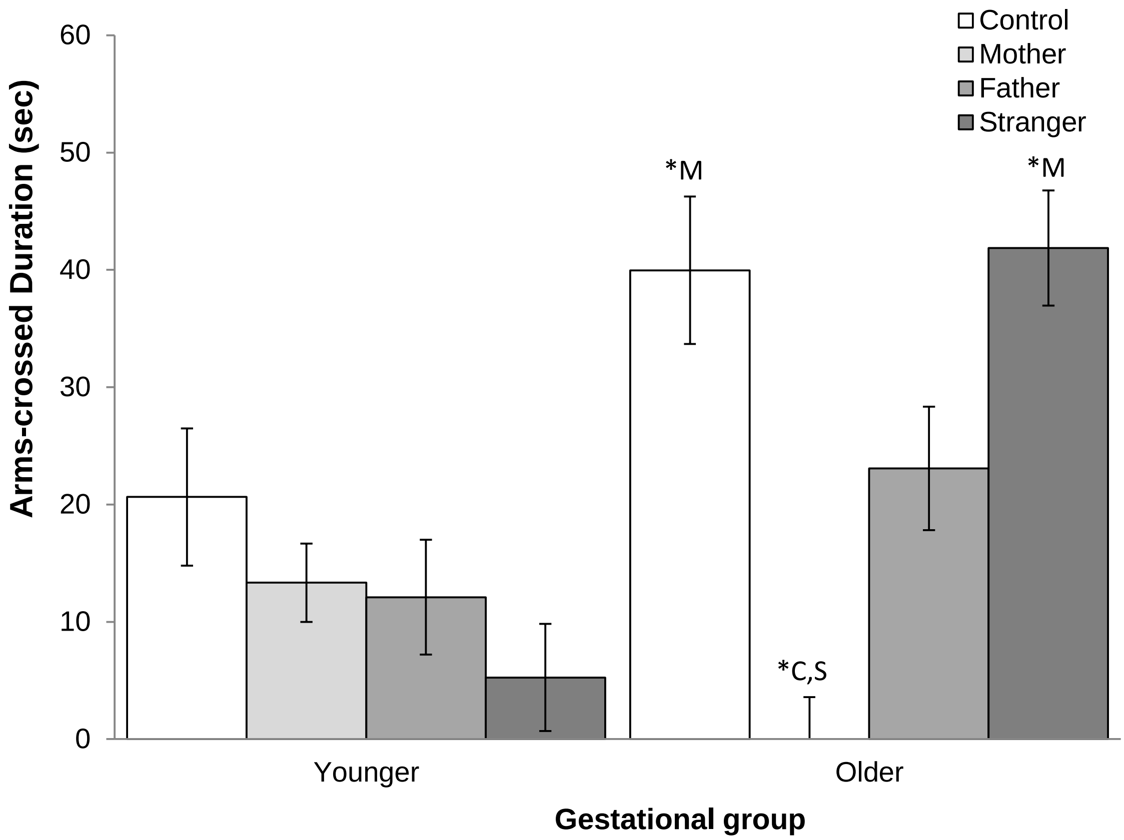

Figure 3.134. Average ‘Arms-crossed’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

90-120s Interval analysis combined

Repeated-measures ANOVA Condition: ‘Self-touch’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Self-touch’ frequency between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (3, 81) = 2.76, p = .048, η_p^2 = .09. Examination of the means suggests that fetuses altered ‘Self-touch’ frequency between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 4.37, p = .046, η_p^2 = .14, of Condition. Overall, there is a decrease produced by the means from ‘Control’ (M = 2.14), to ‘Mother’ (M = 1.65), followed by an increase to ‘Father’ (M = 1.87), and ‘Stranger’ (M = 2.86) producing the quadratic trend.

The post-hoc pairwise comparison revealed no other effects (see Figure 3.135). The means and standard errors can be examined in Table 3.100.

Table 3.100. Means and standard errors (SE) on the frequency of fetuses ‘Self-touch’ across conditions.

	Control	Mother	Father	Stranger
Mean	2.14	1.65	1.87	2.86
SE	0.27	0.33	0.27	0.39

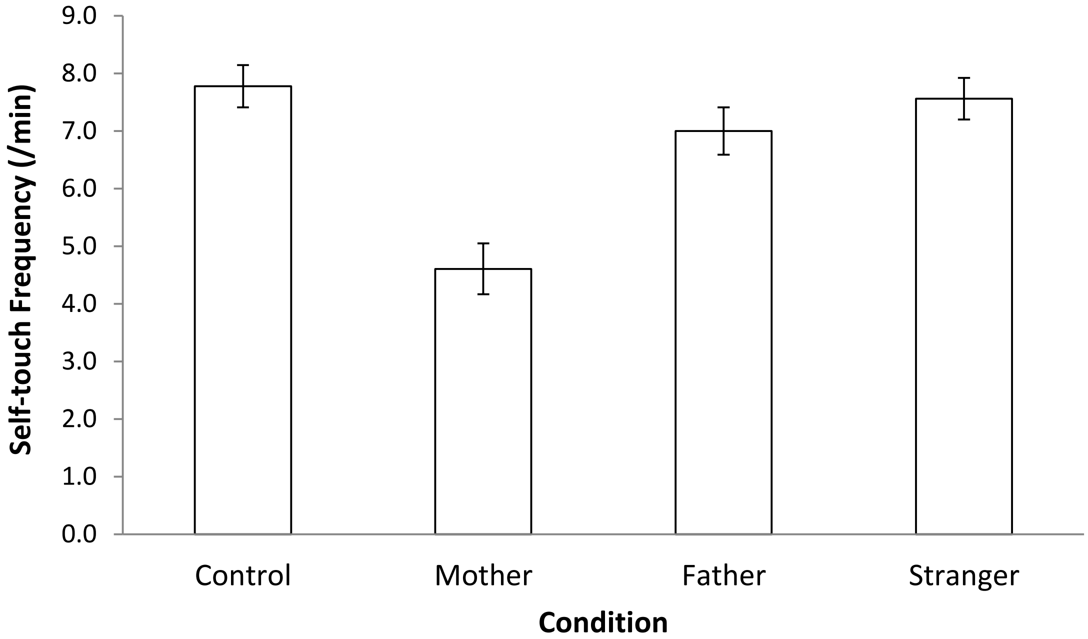

Figure 3.135. Average ‘Self-touch’ frequency (per minute) including standard errors for each condition.

Repeated-measures ANOVA Condition: ‘Self-touch’ Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Self-touch’ duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (3, 81) = 3.60, p = .017, η_p^2 = .12. Examination of the means suggests that fetuses altered 'Self-touch' duration between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 4.57, p = .042, η_p^2 = .15, and a marginally significant cubic trend F (1, 27) = 4.16, p = .051, η_p^2 = .13, of Condition. Overall, there is a decrease produced by the means from 'Control' (M = 7.78), to 'Mother' (M = 4.61), followed by an increase to 'Father' (M = 7.00), and 'Stranger' (M = 7.56) producing the quadratic and cubic trend.

Post-hoc pairwise comparison revealed a marginally significant difference between 'Mother' and 'Control' conditions, with longer 'Self-touch' during 'Control' compared to 'Mother' implying that the fetus touched itself longer during 'Control' (M = 7.78) compared to 'Mother' (M = 4.61, p = .062) (see Figure 3.136). No other effects were found. The means and standard errors can be examined in Table 3.101.

Table 3.101. Means and standard errors (SE) on the duration of fetuses 'Self-touch' across conditions.

	Control	Mother	Father	Stranger
Mean	7.78	4.61	7.00	7.56
SE	0.74	0.89	0.83	0.72

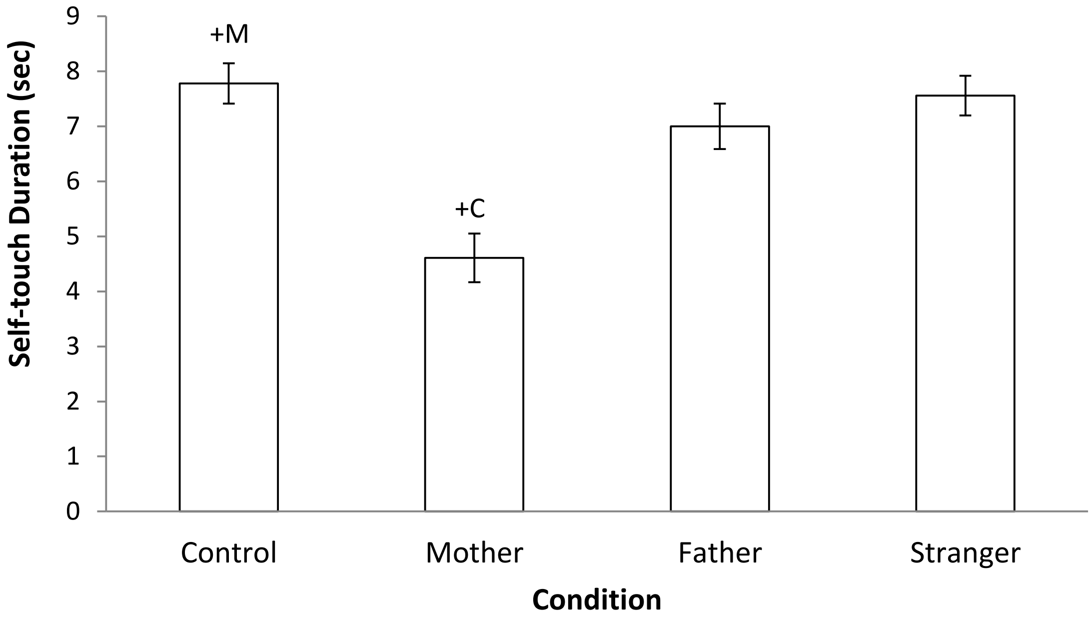

Figure 3.136. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Repeated-measures ANOVA Condition: ‘Inactivity/Resting’ Frequency

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Inactivity/Resting’ frequency between the four Conditions (Control, Mother, Father, Stranger). Results showed a tendency for a main effect of Condition F (3, 81) = 2.36, p = .077, η_p^2 = .08. Examination of the means suggests that fetuses altered ‘Inactivity/Resting’ frequency between Conditions. Polynomial contrasts indicated, in support of this, a marginally significant linear trend, F (1, 27) = 3.56, p = .070, η_p^2 = .12. Overall, there is a decrease produced by the means from ‘Control’ (M = 0.93), to ‘Mother’ (M = 0.43), followed by an increase to ‘Father’ (M = 1.08), and ‘Stranger’ (M = 1.22) producing the linear trend.

The post-hoc pairwise comparison revealed no other effects (see Figure 3.137). No further effects were found. The means and standard errors can be examined in Table 3.102.

Table 3.102. Means and standard errors (SE) on the frequency of fetuses ‘Inactivity/Resting’ across conditions.

	Control	Mother	Father	Stranger
Mean	0.93	0.43	1.08	1.22
SE	0.22	0.19	0.28	0.28

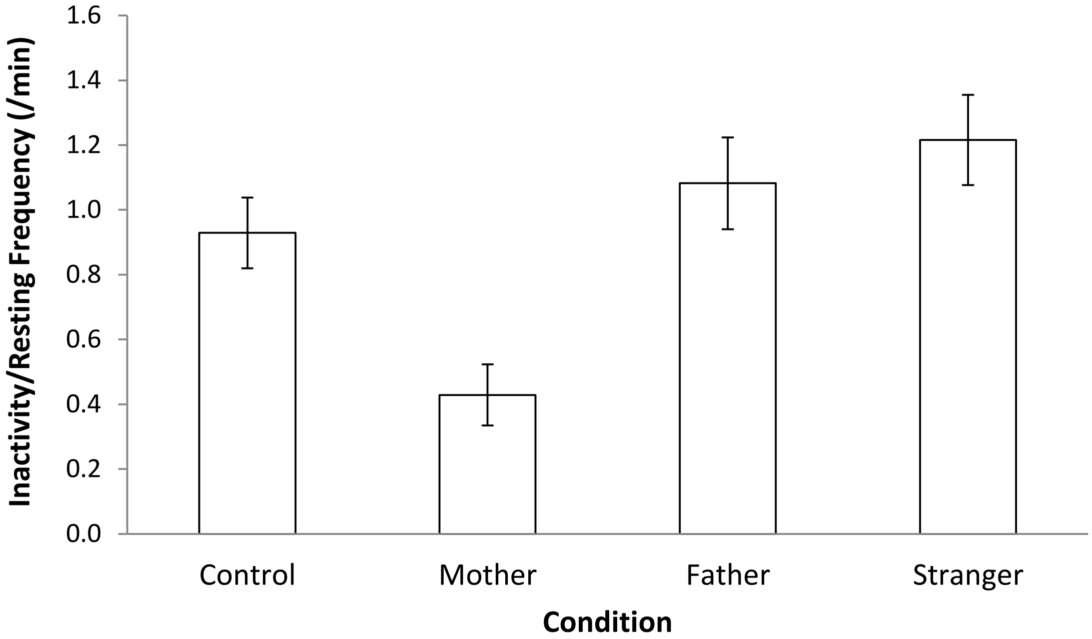

Figure 3.137. Average ‘Inactivity/Resting’ frequency (per minute) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: ‘Self-touch’ Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of ‘Self-touch’. Results showed a significant of main effect of Condition F (3, 78) = 2.78, p = .046, η_p^2 = .10. No significant interaction between Condition and GA, F (3, 78) = 0.77, p = .514, η_p^2 = .03, or main effect of GA F (1, 26) = 0.383, p = .541, η_p^2 = .02, were found. In support of this polynomial contrasts of the main effect of Condition show a significant quadratic trend F (1, 26) = 4.55, p = .043, η_p^2 = .15. Overall, there is a decrease produced by the means from ‘Control’ (M = 2.18) to the ‘Mother’ (M = 1.63) followed by an increase to ‘Father’ (M = 1.88) and ‘Stranger’ (M = 2.86) producing the quadratic trend.

Post-hoc pairwise comparison of the main effect of Condition showed no further effects (see Figure 3.138). No further effects were found. The means and standard errors can be examined in Table 3.103.

Table 3.103. Means and standard errors (SE) of fetuses ‘Self-touch’ frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.04	0.22	2.24	0.24		
Control	1.74	0.36	2.62	0.39	2.18	0.26
Mother	1.87	0.45	1.39	0.48	1.63	0.33
Father	1.73	0.38	2.02	0.40	1.88	0.28
Stranger	2.80	0.54	2.92	0.58	2.86	0.40

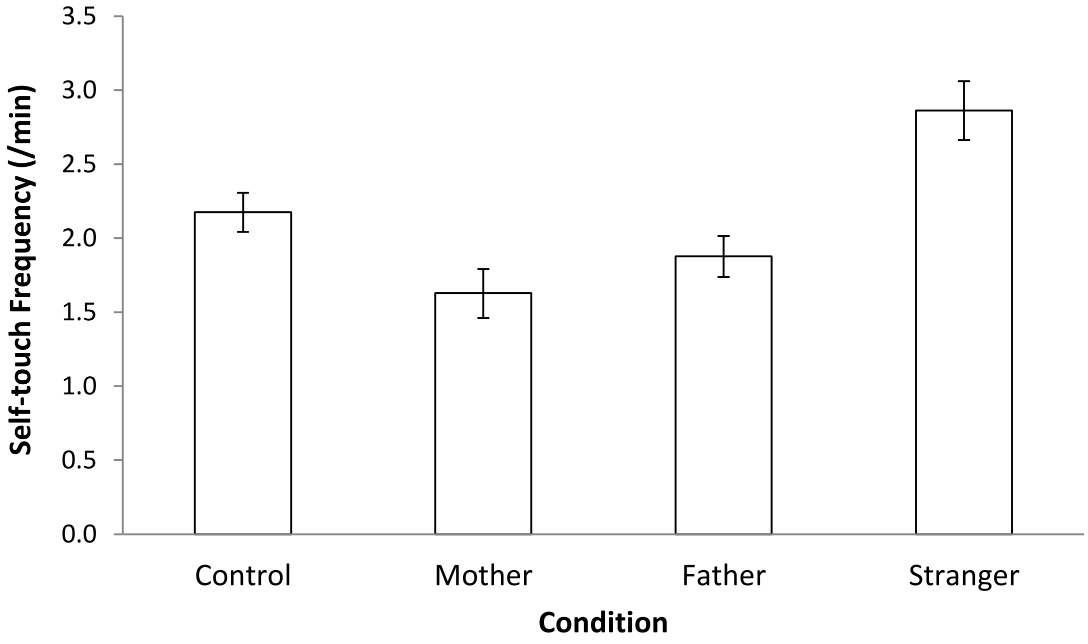

Figure 3.138. Average 'Self-touch' frequency (per minute) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: 'Self-touch' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Self-touch'. Results showed a significant of main effect of Condition F (3, 78) = 3.63, p = .016, η_p^2 = .12. No significant interaction between Condition and GA, F (3, 78) = 1.14, p = .340, η_p^2 = .04, or main effect of GA F (1, 26) = 0.09, p = .764, η_p^2 = .04, were found. In support of this polynomial contrasts of the main effect of Condition show a significant quadratic trend F (1, 26) = 4.33, p = .047, η_p^2 = .14, and a significant cubic trend F (1, 26) = 4.33, p = .048, η_p^2 = .14. Overall, there is a decrease produced by the means from 'Control' (M = 7.84) to the 'Mother' (M = 4.59) followed by an increase to 'Father' (M = 7.01) and 'Stranger' (M = 7.48) producing quadratic and cubic trends.

Post-hoc pairwise comparison of the main effect of Condition revealed a marginally significant difference between 'Control' and 'Mother', with longer 'Self-touch' durations during 'Control' (M = 7.84) compared to 'Mother' (M = 4.59, p = .057) (see Figure 3.139). No further effects were found. The means and standard errors can be examined in Table 3.104.

Table 3.104. Means and standard errors (SE) of fetuses 'Self-touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	6.86	0.61	6.59	0.65		
Control	7.07	1.00	8.61	1.08	7.84	0.74
Mother	4.82	1.23	4.37	1.32	4.59	0.90
Father	6.90	1.15	7.12	1.24	7.01	0.84
Stranger	8.67	0.95	6.28	1.02	7.48	0.70

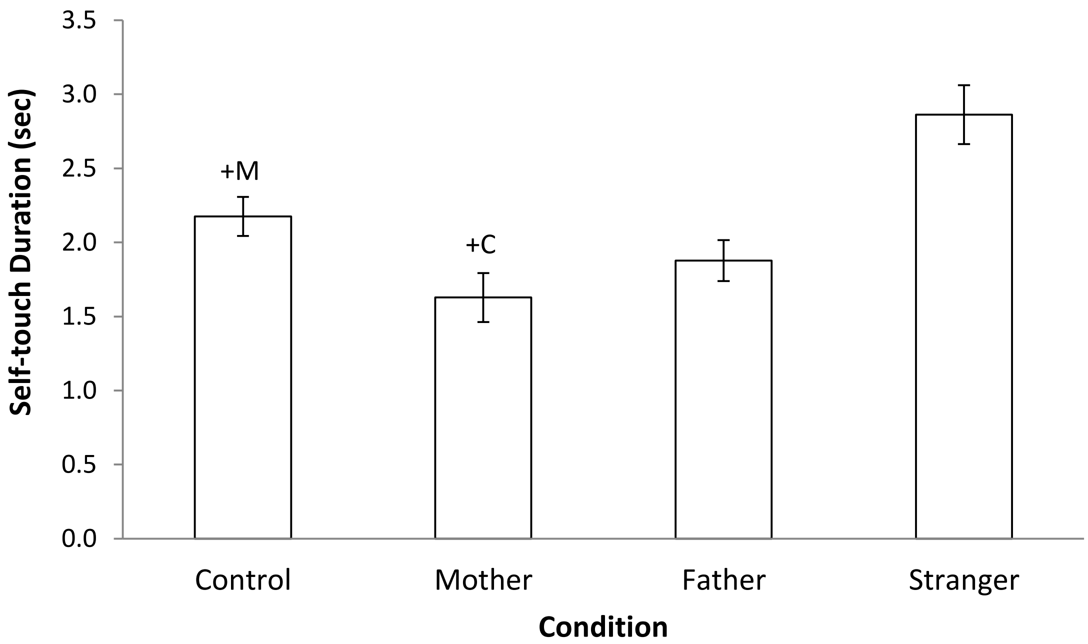

Figure 3.139. Average 'Self-touch' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Inactivity/Resting' Frequency

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the frequency of 'Inactivity/Resting'. The main effect of Condition indicates a marginally significant difference, F (3, 81) = 2.45, p = .069, η_p^2 = .09. Neither a main effect of GA F (1, 26) = 0.44, p = .512, η_p^2 = .02, nor an interaction effect F (3, 81) = 0.84, p = .474, η_p^2 = .03, were found. In support of this polynomial contrasts indicated a marginally significant linear trend F (1, 26) = 3.61, p = .069, η_p^2 = .12, of Condition, indicating a decrease from 'Control' (M = 0.93) to 'Mother' (M = 0.42), followed by an increase to 'Father' (M = 1.07), and 'Stranger' (M = 1.24).

Post-hoc pairwise comparison of the Condition main effect showed a marginally significant difference between 'Mother' and 'Stranger' with a higher frequency of 'Inactivity/Resting' in 'Stranger' (M = 1.24) compared to 'Mother' (M = 0.42, p = .087) (see Figure 3.140). No further effects were found. The means and standard errors can be examined in Table 3.105.

Table 3.105. Means and standard errors (SE) of fetuses 'Inactivity/Resting' frequency across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	0.87	0.21	0.97	0.23		
Control	0.80	0.30	1.08	0.32	0.94	0.22
Mother	0.53	0.26	0.31	0.28	0.42	0.19
Father	1.20	0.39	0.95	0.42	1.07	0.29
Stranger	0.94	0.38	1.54	0.41	1.24	0.28

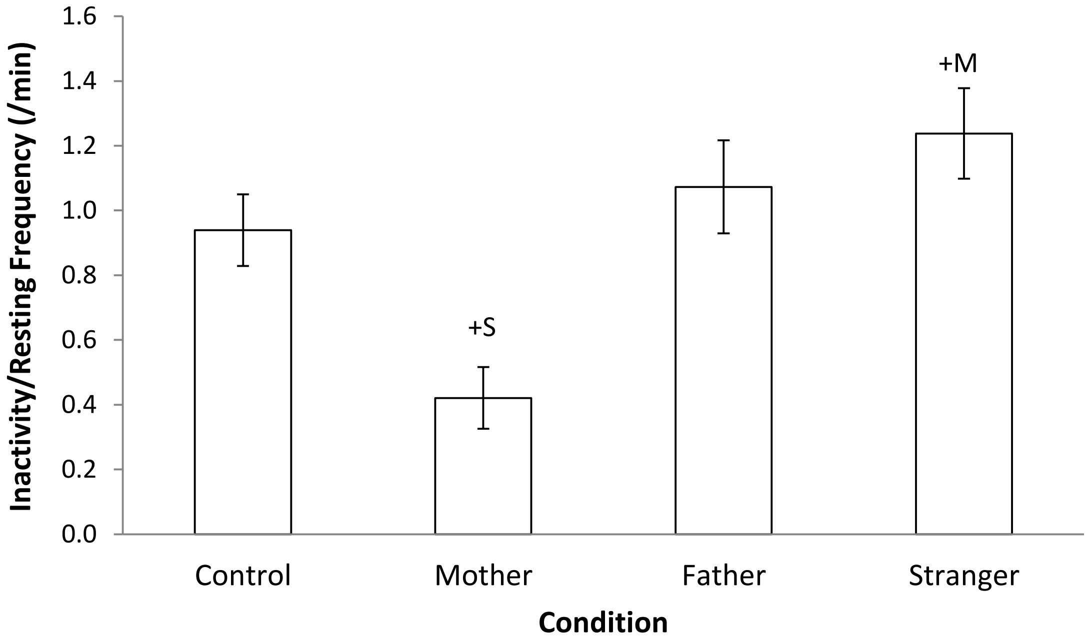

Figure 3.140. Average ‘Inactivity/Resting’ frequency (per minute) including standard errors for each condition (.05 ≥+≤ .10).

0-120s Interval

Repeated-measures ANOVA Condition: ‘Hand movement’ Frequency

A repeated-measures ANOVA, using Greenhouse-Geisser correction, was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) on the frequencies of ‘Hand movements’. Results showed a tendency between Conditions F (1.20, 32.47) = 2.88, p = .093, η_p^2 = .10. Examination of the means suggests that fetuses tend to alter ‘Hand movement’ frequency depending on Condition. Polynomial contrasts indicated, in support of this, a tendency for a quadratic trend, F (1, 27) = 3.16, p = .087, η_p^2 = .11, as well as a tendency towards a cubic trend F (1, 27) = 2.99, p = .095, η_p^2 = .10. Overall, there is an increase produced by the means from ‘Control’ (M = 2.48) to ‘Mother’ (M = 10.52). However, ‘Father’ (M = 2.57) has a somewhat lower mean which drops further to ‘Stranger’ (M = 2.48), producing the quadratic and cubic tendency.

The post-hoc pairwise comparison did not reveal any further effects (see Figure 3.141). The means and standard errors can be examined in Table 3.106.

Table 3.106. Means and standard errors (SE) on the frequency of fetuses 'Hand movements' across conditions.

	Control	Mother	Father	Stranger
Mean	2.48	10.52	2.57	2.48
SE	1.08	5.02	1.18	1.00

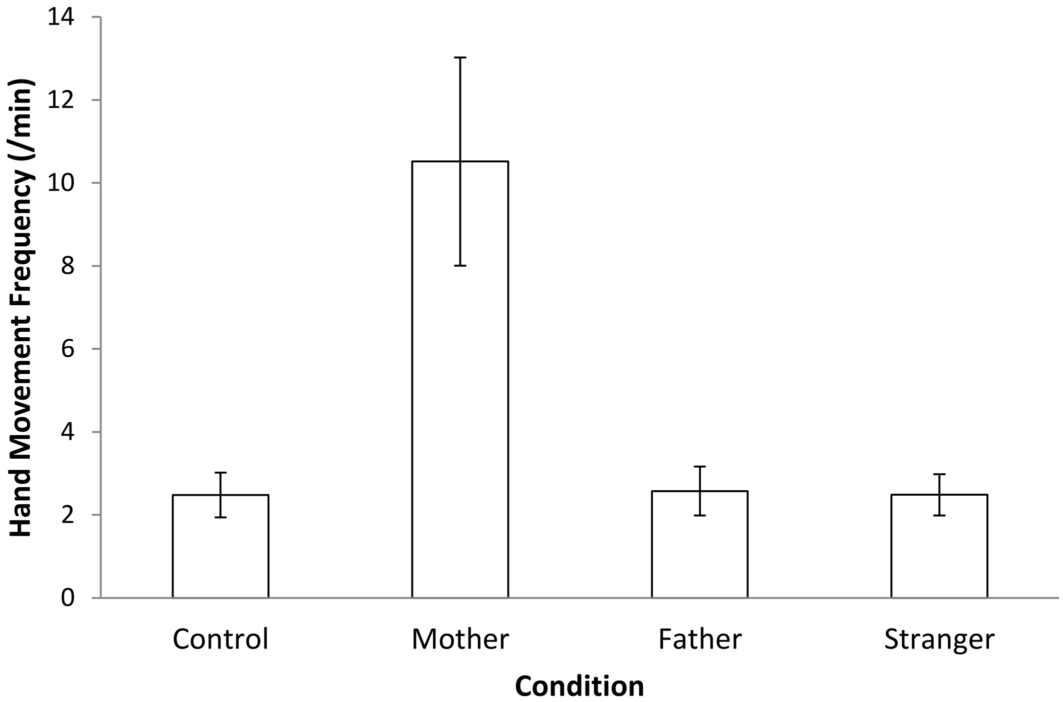

Figure 3.141. Average 'Hand movement' frequency (per minute) including standard errors for each condition.

Mixed-design ANOVA Condition*GA: 'Uterus touch' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the durations of 'Uterus touch'. Results showed a tendency of an interaction between Condition and GA, F (3, 78) = 2.58, p = .060, η_p^2 = .09. However, no main effect of Condition F (3, 78) =

1.86, p = .144, η_p^2 = .07, or a significant main effect of GA F (1, 26) = 0.02, p = .888, η_p^2 < .01, were found. Polynomial contrasts indicated, in support of this, a significant linear trend for the interaction F (1, 27) = 7.08, p = .012, η_p^2 = .21.

Post-hoc pairwise comparison of the main effect of the interaction revealed a significant difference in 'Control' with younger fetuses (M = 26.41) touching the uterus longer compared to older fetuses (M = 3.24, p = .037). A tendency was observed in 'Stranger', with older fetuses (M = 28.68) touching the uterus longer compared to younger fetuses (M = 7.48, p = .050). Older fetuses showed a tendency between 'Control' and 'Mother', with increased 'Uterus touch' duration during maternal stimulation (M = 34.90) compared to 'Control' (M = 3.24, p = .080). Older fetuses showed a further tendency between 'Control' and 'Stranger' conditions, with increased 'Uterus touch' duration in 'Stranger' (M = 28.68) compared to 'Control' (M = 3.24, p = 0.67) (see Figures 3.142 and 3.143). No further effects were found. The means and standard errors can be examined in Table 3.107.

Table 3.107. Means and standard errors (SE) of fetuses 'Uterus touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	21.65	5.13	20.58	5.52		
Control	26.41	7.17	3.24	7.70	14.83	5.26
Mother	30.50	10.80	34.90	11.60	32.70	7.92
Father	22.20	8.74	15.49	9.38	18.84	6.41
Stranger	7.48	7.04	28.68	7.56	18.08	5.16

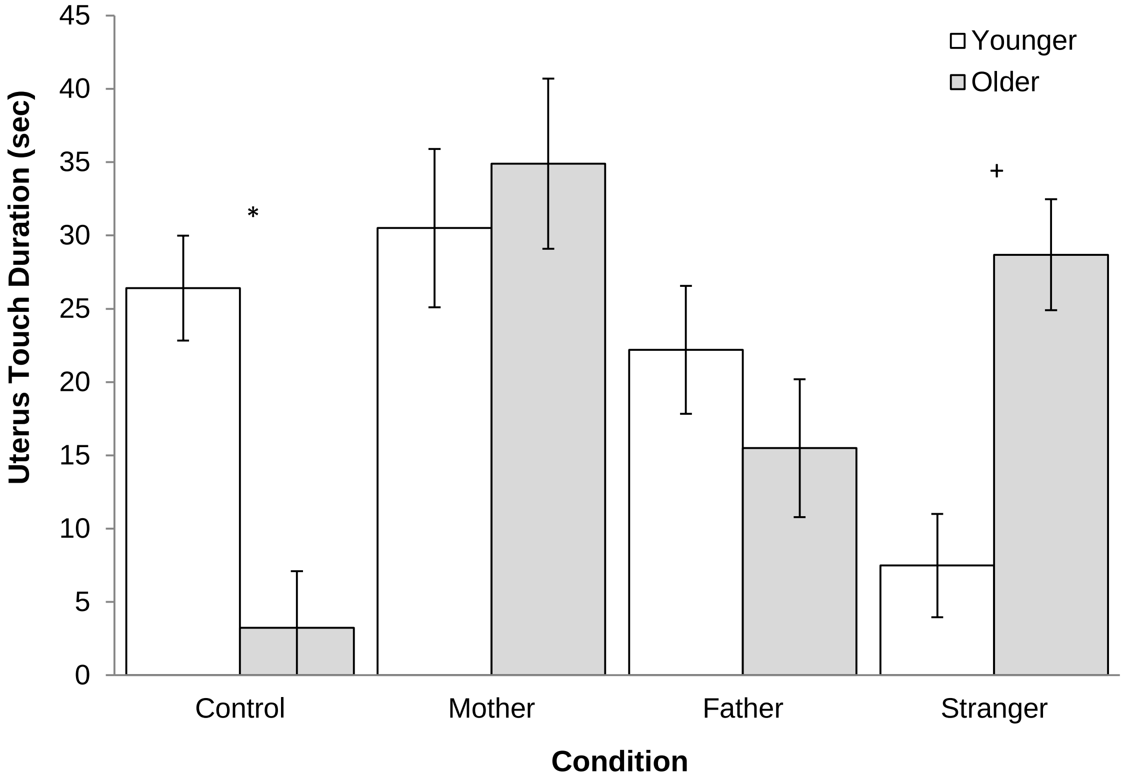

Figure 3.142. Average ‘Uterus touch’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *< .05).

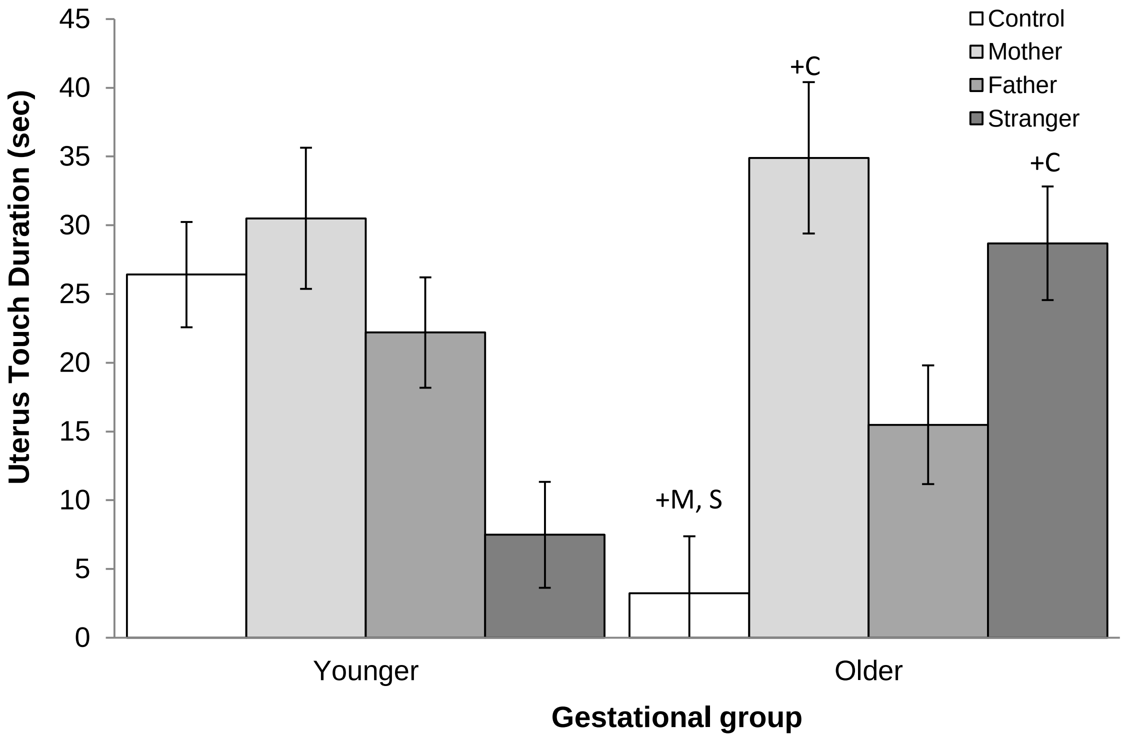

Figure 3.143. Average ‘Uterus touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (.05 ≥+≤ .10)

Mixed-design ANOVA Condition*GA: ‘Arms-crossed’ Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the durations of ‘Arms-crossed’ behaviour. Results showed a tendency for an interaction between Condition and GA, F (3, 78) = 2.18, p = .098, η_p^2 = .08, and a tendency for a main effect of GA F (1, 26) = 3.52, p = .072, η_p^2 = .12, were found. However, no significant main effect of Condition F (3, 78) = 2.04, p = .115, η_p^2 = .07, was found. In support of this polynomial contrasts of the interaction tendency for a quadratic trend for Condition and GA F (1, 26) = 3.37, p = .078, η_p^2 = .12.

Post-hoc pairwise comparison of the main effect of GA revealed that older fetuses (M = 26.21) tend to cross the arms longer compared to younger fetuses (M = 12.08, p = .072) (see Figure 3.146).

Post-hoc pairwise comparison of the interaction revealed a significant difference in the ‘Stranger’ condition, with older fetuses (M = 43.71) displaying an increased duration of ‘Arms-crossed’ compared to younger fetuses (M = 8.06, p = .014). Older fetuses showed significant differences between ‘Mother’ and ‘Stranger’, with longer arm-crossed in ‘Stranger’ (M = 43.71) compared to mother’s touch (M = 4.18, p = .016) (see Figures 3.144 and 3.145). No further effects were found. The means and standard errors can be examined in Table 3.108.

Table 3.108. Means and standard errors (SE) of fetuses ‘Arms-crossed’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	12.08	5.13	26.21	5.51		
Control	16.66	9.97	33.65	10.71	25.15	7.32
Mother	11.04	5.84	4.18	6.27	7.61	4.28
Father	12.58	9.06	23.32	9.73	17.95	6.65
Stranger	8.06	9.32	43.71	10.01	25.89	6.64

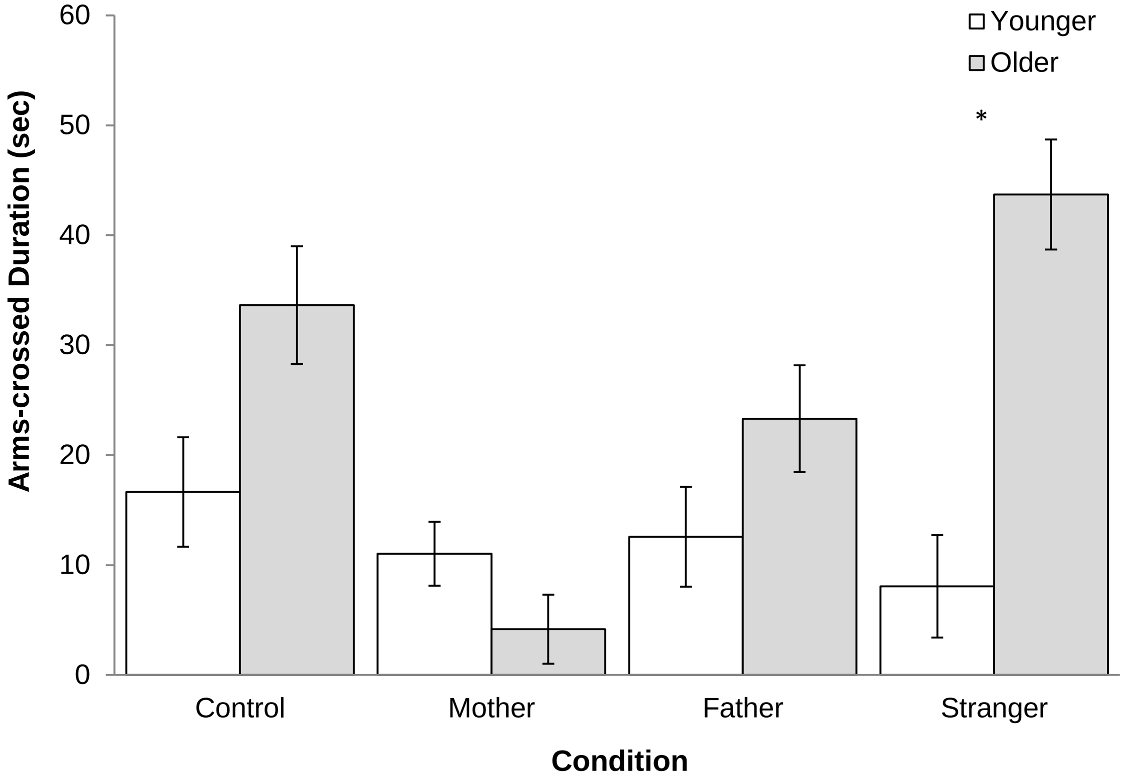

Figure 3.144. Average ‘Arms-crossed’ duration (in seconds) including standard errors for each condition (*< .05).

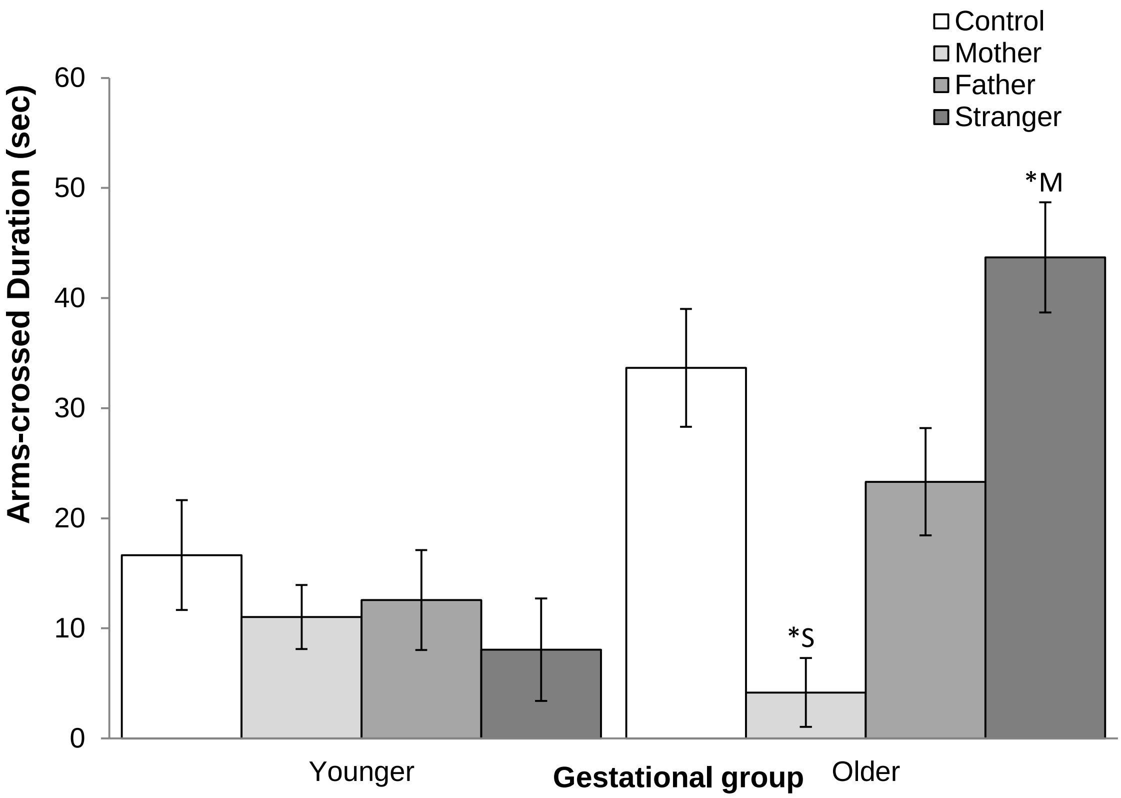

Figure 3.145. Average ‘Arms-crossed’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

Figure 3.146. Average ‘Arms-crossed’ duration (in seconds) including standard errors for GA (younger and older fetuses) (.05 ≥+≤ .10).

0-120 Interval analysis combined

Repeated-measures ANOVA Condition: ‘Self-touch’ Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in ‘Self-touch’ duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a significant main effect of Condition F (3, 81) = 3.57, p = .018, η_p^2 = .12. Examination of the means suggests that fetuses altered ‘Self-touch’ duration between Conditions. Polynomial contrasts indicated, in support of this, a significant quadratic trend, F (1, 27) = 7.77, p = .010, η_p^2 = .22, of Condition. Overall, there is a decrease produced by the means from ‘Control’ (M = 8.25), to ‘Mother’ (M = 5.49), followed by an increase to ‘Father’ (M = 7.18), and ‘Stranger’ (M = 7.98) producing the quadratic trend.

Post-hoc pairwise comparison revealed a significant difference between ‘Mother’ and ‘Control’ conditions, with longer ‘Self-touch’ during ‘Control’ compared to ‘Mother’ implying that the fetus touched itself longer during ‘Control’ (M = 8.25) compared to ‘Mother’ (M = 5.49, p = .028) (see Figure 3.147). No other effects were found. The means and standard errors can be examined in Table 3.109.

Table 3.109. Means and standard errors (SE) on the duration of fetuses ‘Self-touch’ across conditions.

	Control	Mother	Father	Stranger
Mean	8.25	5.49	7.18	7.98
SE	0.56	0.77	0.70	0.58

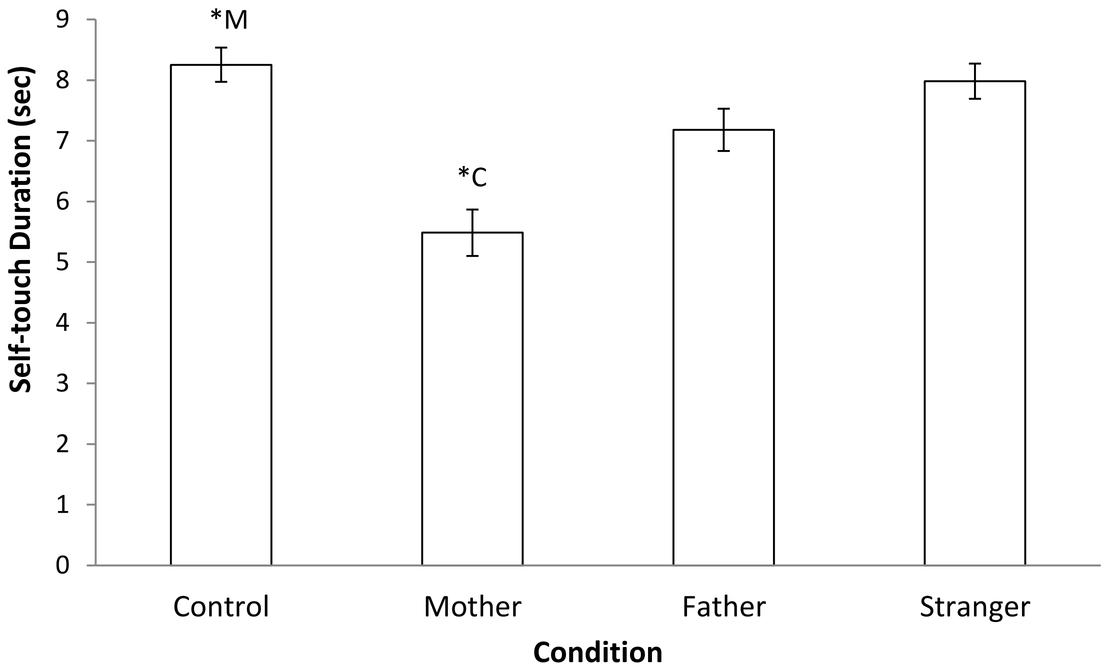

Figure 3.147. Average 'Self-touch' duration (in seconds) including standard errors for each condition (*< .05).

Repeated-measures ANOVA Condition: 'Inactivity/Resting' Duration

A repeated-measures ANOVA was conducted to assess whether there are differences in 'Inactivity/Resting' duration between the four Conditions (Control, Mother, Father, Stranger). Results showed a marginally significant main effect of Condition F (3, 81) = 2.45, p = .069, η_p^2 = .08. Examination of the means suggests that fetuses altered 'Inactivity/Resting' duration between Conditions. Polynomial contrasts indicated, in support of this, a significant cubic trend, F (1, 27) = 5.92, p = .022, η_p^2 = .18. Overall, there is a decrease produced by the means from 'Control' (M = 3.92), to 'Mother' (M = 1.80), followed by an increase to 'Father' (M = 4.32), and a slight decrease to 'Stranger' (M = 4.19) producing the cubic trend.

Post-hoc pairwise comparison revealed a marginally significant difference between 'Mother' and 'Father' conditions, with a longer 'Inactivity/Resting' duration during father's touch compared to 'Mother' implying that the fetus was more active when the mother (M = 1.80) touched compared to the father (M = 4.32, p = .096) (see Figure 3.148). No further effects were found. The means and standard errors can be examined in Table 3.110.

Table 3.110. Means and standard errors (SE) on the duration of fetuses 'Inactivity/Resting' across conditions.

	Control	Mother	Father	Stranger
Mean	3.92	1.80	4.32	4.19
SE	0.88	0.64	0.90	0.86

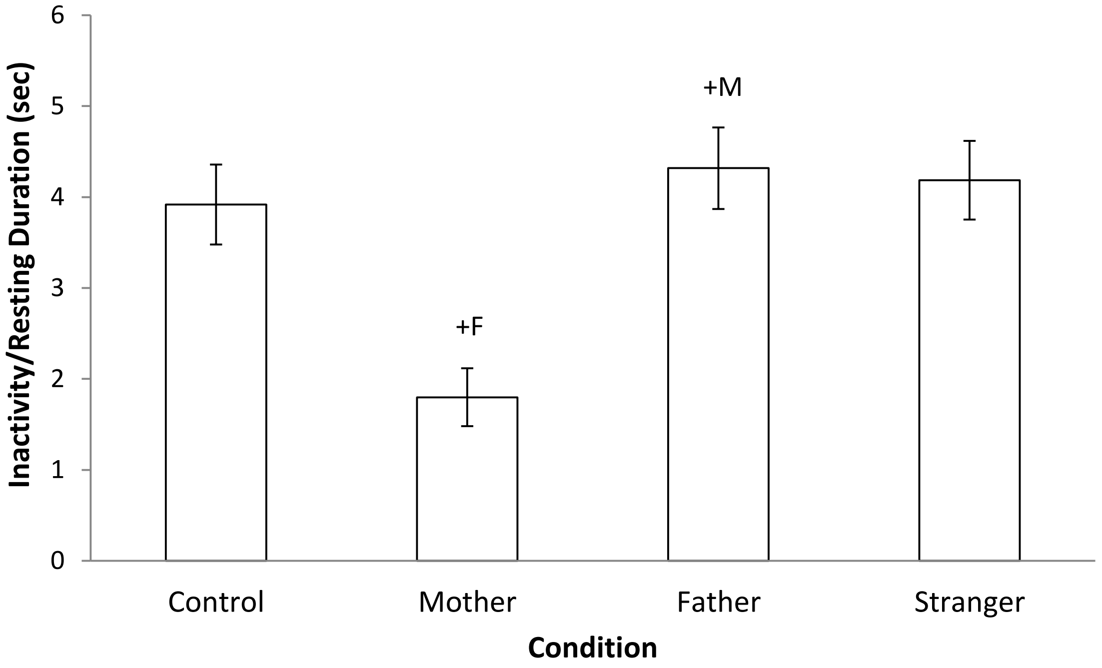

Figure 3.148. Average 'Inactivity/Resting' duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10).

Mixed-design ANOVA Condition*GA: 'Self-touch' Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of 'Self-touch'. Results showed a significant of main effect of Condition F (3, 78) = 3.79, p = .014, η_p^2 = .13, and a marginally significant interaction between Condition and GA, F (3, 78) = 2.25, p = .089, η_p^2 = .08. No main effect of GA F (1, 26) = 0.01, p = .980, η_p^2 < .001, was found. In support of this polynomial contrasts of the main effect of Condition show a significant quadratic trend F (1, 26) = 7.37, p = .012, η_p^2 = .22. Overall, there is a decrease produced by the means from

'Control' (M = 8.33) to the 'Mother' (M = 5.47) followed by an increase to 'Father' (M = 7.20) and 'Stranger' (M = 7.90) producing the quadratic trend. Polynomial contrasts of the interaction show a significant linear trend of Condition and GA F (1, 26) = 6.76, p = .015, $\eta_p^2 = .21$.

Post-hoc pairwise comparison of the main effect of Condition revealed a significant difference between 'Control' and 'Mother', with longer 'Self-touch' durations during 'Control' (M = 8.33) compared to 'Mother' (M = 5.47, p = .019) (see Figure 3.149).

Post-hoc pairwise comparison of the interaction between Condition and GA revealed a marginally significant difference in 'Control' for younger and older fetuses, with older fetuses (M = 9.40) engaging in longer 'Self-touch' compared to younger fetuses (M = 7.26, p = .056). A significant difference can be observed in 'Stranger', with younger fetuses (M = 9.13) engaging in longer 'Self-touch' than older fetuses (M = 6.67, p = .033). A further significant difference can be seen for older fetuses, who engage in longer 'Self-touch' in 'Control' (M = 9.40) compared to 'Mother' (M = 5.24, p = .020). Lastly, a significant difference for older fetuses was found in 'Control' compared to 'Stranger' with longer durations of 'Self-touch' in 'Control' (M = 9.40) compared to 'Stranger' (M = 6.67, p = .046) (see Figures 3.150 and 3.151). No further effects were found. The means and standard errors can be examined in Table 3.111.

Table 3.111. Means and standard errors (SE) of fetuses 'Self-touch' duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	7.23	0.45	7.22	0.49		
Control	7.26	0.73	9.40	0.78	8.33	0.53
Mother	5.69	1.07	5.25	1.14	5.47	0.78
Father	6.85	0.97	7.56	1.04	7.20	0.71
Stranger	9.13	0.74	6.67	0.80	7.90	0.55

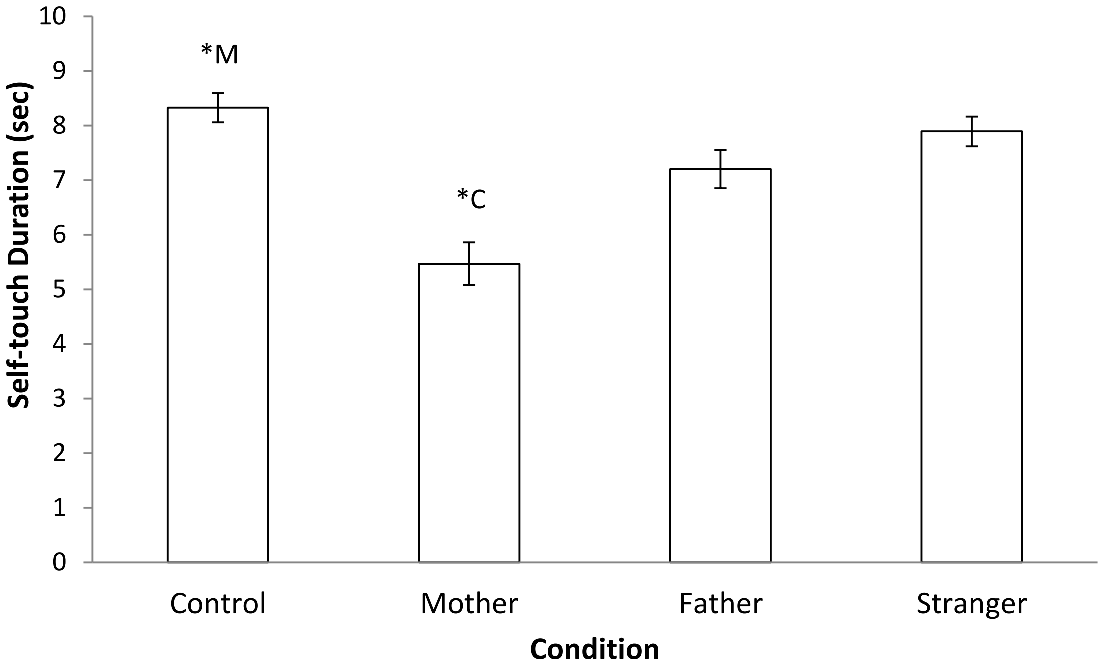

Figure 3.149. Average 'Self-touch' duration (in seconds) including standard errors for each condition (*< .05).

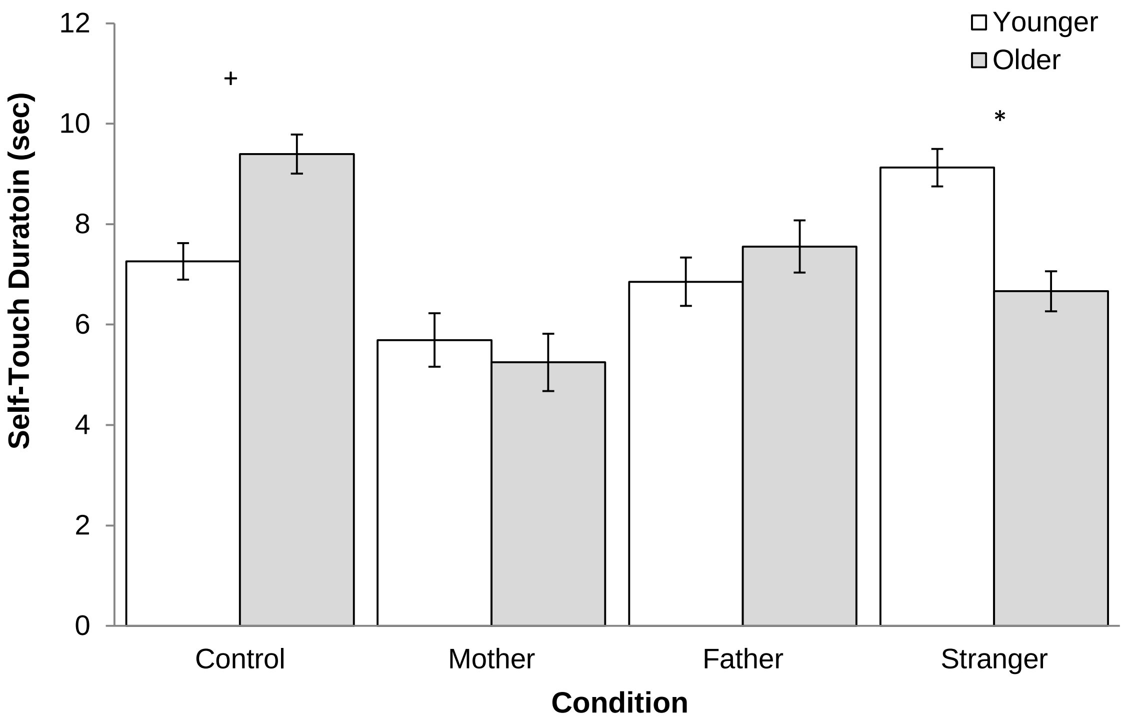

Figure 3.150. Average ‘Self-touch’ duration (in seconds) including standard errors for each condition (.05 ≥+≤ .10, *<.05).

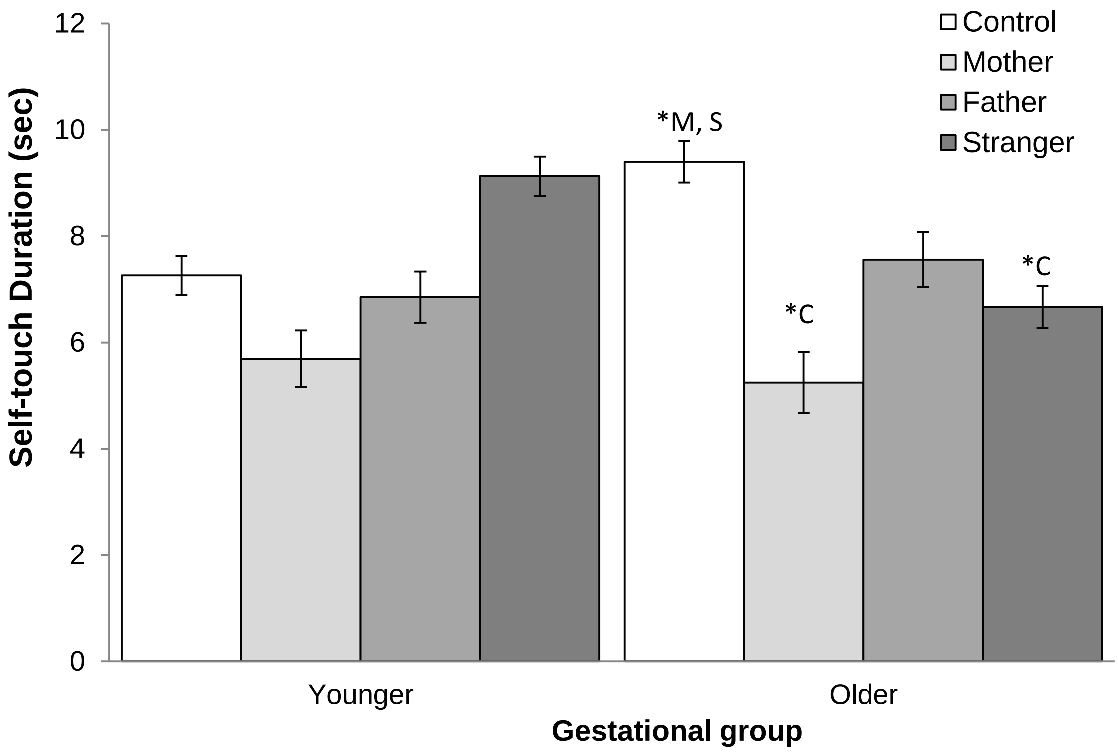

Figure 3.151. Average ‘Self-touch’ duration (in seconds) including standard errors for all four conditions between gestational ages (younger and older fetuses) (*< .05).

Mixed-design ANOVA Condition*GA: ‘Inactivity/Resting’ Duration

A mixed-design ANOVA was conducted to assess the effect of Condition (Control, Mother, Father, Stranger) and GA on the duration of ‘Inactivity/Resting’. The main effect of Condition indicates a marginally significant difference, F (3, 78) = 2.71, p = .051, η_p^2 = .09. Neither a main effect of GA F (1, 26) = 1.87, p = .183, η_p^2 = .02, nor an interaction effect F (3, 78) = 1.88, p = .140, η_p^2 = .07, were found. In support of this polynomial contrasts indicated a significant cubic trend F (1, 26) = 5.65, p = .025, η_p^2 = .18, of Condition was found, indicating a decrease from ‘Control’ (M = 3.98) to ‘Mother’ (M = 1.78), followed by an increase to ‘Father’ (M = 4.32) and ‘Stranger’ (M = 4.33).

Post-hoc analysis of the main effect of Condition did not reveal any further effects (see Figure 3.152). No further effects were found. The means and standard errors can be examined in Table 3.112.

Table 3.112. Means and standard errors (SE) of fetuses ‘Inactivity/Resting’ duration across conditions and gestational ages as well as pairwise comparisons.

	Younger Fetuses (<27 weeks GA)		Older Fetuses (=> 28 weeks GA)		Across Conditions	
	Mean	SE	Mean	SE	Mean	SE
Across GA	2.92	0.68	4.28	0.73		
Control	3.09	1.20	4.87	1.29	3.98	0.88
Mother	2.03	0.89	1.53	0.95	1.78	0.65
Father	4.27	1.25	4.37	1.34	4.32	0.92
Stranger	2.30	1.07	6.36	1.15	4.33	0.79

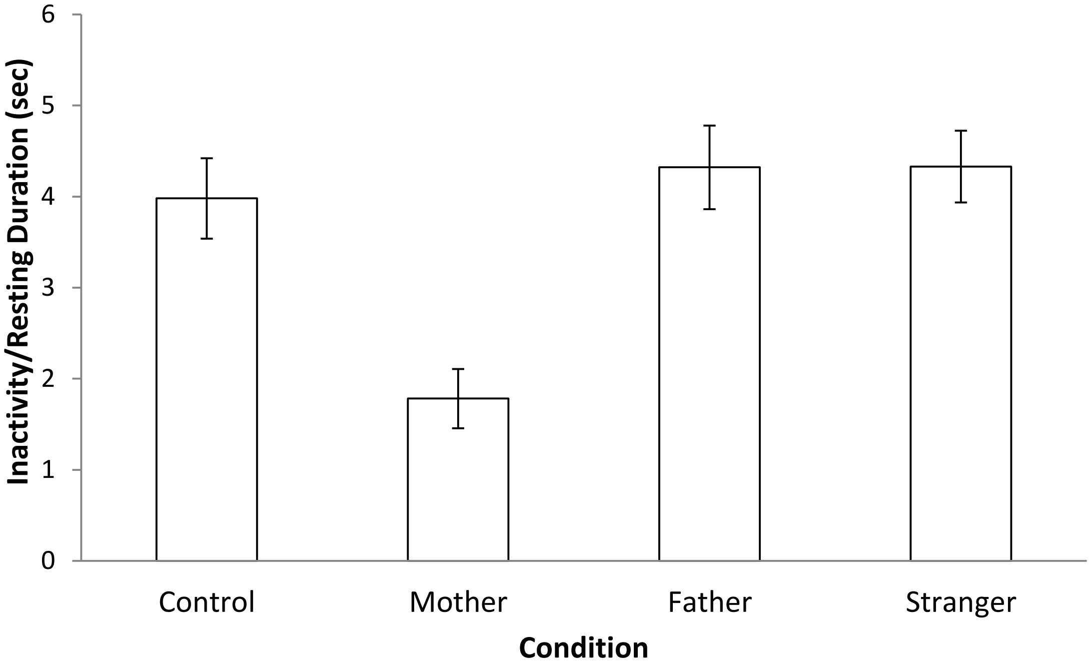

Figure 3.152. Average ‘Inactivity/Resting’ duration (in seconds) including standard errors for each condition.

Discussion

The overall aim of the present study aimed to compare different types of abdominal touch: when mother, father, and stranger touched the maternal abdomen, compared to a control (no-touch, silent) condition.

Aim 1: Responses to tactile stimulation

It was hypothesised (**Hypothesis 1a**) that fetuses will respond differentially between mothers' touch and the control condition.

Since the data was analysed over multiple time intervals, the most commonly used analysis, over the whole 0-120 period of the experiment will be presented first. Over the entire 2-minute stimulation, the fetus tended to engage in longer 'Uterus touch' when the mother touched her abdomen, compared to the control condition. The fetus also engaged in significantly more self-stimulation (measured as 'Self-touch') during the control condition compared to when the mother was touching.

When including results from the time interval analysis a pattern becomes clear. Fetal self-directed touch ('Body touch' and 'Self-touch') appears to be the highest in the control condition compared to when the mother touched, which appears to have the lowest time spent in self-engagement. When the mother touches outward directed movements such as 'Uterus touch' or 'Face press' (when the fetuses presses its own face against the inside of the uterus) become most prominent, suggesting that the fetus is seeking out or wanting to experience the maternal stimulation, and when no stimulation is present the fetus engages in self-stimulation instead.

The third most frequently appearing result was 'Inactivity/Resting', during control condition. When the mother was touching the abdomen, however, the fetus had the lowest scores of inactivity.

Thus these results do support **Hypothesis 1a**, in that fetuses responded differentially between mother's touch and the control condition.

Hypothesis 1b stated that in relation to Hypothesis 1, it was hypothesised that there would be more externally directed movements instead of self-directed movements, such as fetuses hands touching the uterus or pressing their face against the uterine abdominal wall, when the mother touches the abdomen compared to control and other tactile stimulation, if mothers touch has unique properties. Our data clearly shows that the fetus does engage in more externally directed movements, especially the duration of the 'Uterus touch' stands out in various time-intervals, showing that the fetus engages in more 'Uterus touch' when the mother touches compared to control, as well as father's and stranger's touch. The strongest results are again those that appear over the entire 2-minute stimulation. The two most outstanding findings are those concerning the duration of the fetus touching the uterus, which shows hardly any engagement during the control condition and most engagement during mother's touch. The fetus also appears to engage in 'Uterus touch' during father's and stranger's touch, with a slightly stronger response for the stranger over the father. This result is also reflected in the contrasting variable of 'Self-touch'. Significant differences were found between the control condition and mothers' touch, with highest scores on 'Self-touch' during the control condition and lowest scores during maternal touch. Slightly more self-touch occurred during father's touch and even more during stranger's touch, with 'Self-touch' during stranger's touch being similar to that of control. These results are consistent across conditions and become even stronger when gestational age is taken into account, including the same pattern for older fetuses.

Over the course of the 2-minute stimulation effects of condition show a consistent pattern throughout the first minute of stimulation for 'Face press' frequencies and durations. The fetus presses its face against the least during the control condition. The strongest tendency can be found during father's touch, followed by mother's touch, and stranger's touch which is close to the level of the control condition. During the second minute of stimulation, and its belonging time intervals, the pattern changes ever so slightly, with responses to both mother's and father's touch being almost level, and responses to control and strangers' touch being similar and lower.

The duration of the 'Uterus touch' during the first minute of stimulation and its included time intervals shows a consistent pattern where mother's touch tends to be the strongest, compared to control, followed by stranger's and then father's touch. The order of touch durations changes slightly during the following minute, with the response to father's touch falling and mothers' touch taking the lead in longest 'Uterus touch' duration across conditions followed by stranger's touch and then father's, while 'Uterus touch' during control remains almost non-existent.

Results for 'External touch' duration between conditions during the first minute of stimulation are almost non-existent for the control condition but are almost equally as long for all three other conditions, with the strongest response for father's touch, immediately follows by mother's and stranger's touch. These results change ever so slightly as the course of the stimulation continues, external touch for the control condition increases slightly and is now almost level with stranger's touch, however, parental touch is still superior to these two conditions eliciting a longer response which is now almost equal, too.

Overall, in relation to **Hypothesis 1b**, it can be stated that the mother's touch appears to be the producing strongest externally directed responses and the lowest self-directed responses. As there are no significant differences found between mother's and father's or stranger's responses we can assume that the responses are not too different between touches, however as responses to mother's touch are consistently statistically different from control, whereas responses to the other conditions are not, it can be assumed that mothers elicit a unique response from the fetus, especially regarding externally directed movement. Thus it appears that we can accept the research **Hypothesis 1b**, that there would be more externally directed movements instead of self-directed movements when the mother touches the abdomen compared to control and other tactile stimulation.

Hypothesis 1c expected to find increased arm movements and head movements during maternal stimulation compared to control, as well as differential responses in fetal touch. Findings showed that increased arm movement frequencies are especially found within the first 10 and 15 seconds. Strongest responses are found for mother's touch which is immediately followed by father's touch. Responses to stranger's touch are somewhat weaker and responses to no stimulation are the least frequent. Then the differences between conditions disappear until the second minute of the stimulation where the pattern has now shifted, 'Arm movements' in response to the stranger's touch increases as does the 'Arm movement' frequency for the control condition. The response to maternal stimulation is still the highest, whereas responses to the fathers' have decreased.

Connected to the 'Arm movements' are 'Hand movements', which differentiate mostly in the second half of the stimulation period (60-120s). The longest 'Hand movements' can be found during mother's touch. 'Hand movements' appear to be much shorter during father's touch, followed by even shorter and almost identical times during control and stranger's touch. These results are visible throughout the whole 2-minutes of stimulation highlighting again that the fetal response to mother's touch is the strongest and that there are further differences to be seen between conditions, although the response to the stranger's touch is somewhat similar to the control, thus provoking the weakest response in this domain.

Interestingly the results reflect the findings from the opposing variables, 'Inactivity/Resting' throughout the stimulation. Throughout the experiment (0-120s) the fetuses appear to be most inactive during father's and stranger's touch and control, whereas the least inactivity was found during mother's touch. The initial response (0-10s) shows most inactivity for control and stranger's touch. The fetuses appear the least inactive during mother's touch and show a medium inactivity for father's touch. This pattern continues throughout the stimulation period, and over time the fetus increases inactivity towards the father's touch until the fetus is mainly active during mothers' touch and not during any of the other conditions, which coincide with the control condition.

Thus the data has shown that the fetus responds differentially to the different touches, with strongest responses to the mother's touch in 'Arm'- and 'Head movements'. Although the response changes throughout the stimulation period, the overall results (0-120s) show a clear pattern with the response to the mother is the strongest compared to other tactile stimulations. We can, therefore, accept **Hypothesis 1c**.

Hypothesis 2 examined if fetuses respond to tactile stimulation overall (regardless of who touches the mother's abdomen) compared to the control condition. Specifically, it was expected that there would be increases in movements to the external stimulation, possible differences in the intensity of the response between mother, father, and stranger if the fetus is capable of discriminating between touches. Findings from this experiment support **Hypothesis 2** as differences between control and tactile stimulations were observed across the examined variables. Movement responses ('Arm movements', 'Head movements', 'Hand movements', and 'General movements') were the weakest to the control condition and appeared strongest and most consistent for the mother's touch. Responses to father's touch were strong initially at the start of the stimulation and abated over time. Responses to the stranger's touch tended to be stronger than the response to the control condition, however, declined rapidly and assimilated to that of the control.

Similar findings were found for fetuses with tactile responses. Externally directed touch ('Uterus touch', 'Face press', 'External touch') responses to mother were the strongest, followed by fathers', strangers' and control. As already previously discussed, over the course of the stimulation the responses to the father and stranger changed the most, however it remains apparent that responses to tactile stimulation remain different to control, and we can, therefore, accept **Hypothesis 2** and assume that fetuses response to tactile stimulation overall and their response differs to that of the no-touch control condition.

Hypothesis 3 examined whether fetuses were capable of responding differently to father's and stranger's touch. The data showed no significant differences or tendencies between father's and stranger's touch. Although there are significant models of condition as well as tendencies to be found, the differences between the conditions appear to be too small, or the standard error too large, to show differences in the post-hoc analysis. However, when expecting the means of the significant models of condition significant differences and tendencies lie mostly between strangers and mothers touch, with the mother eliciting the strongest response and the stranger the weakest – most control like response and the father lies somewhat between the two. These effects can be found across the examined variables. Stranger's and father's touch appear to be either rather similar or the difference between the two is very small. Thus our results do hint that there is a differential response between father and stranger, this response, however, appears to be much more delicate than the large differentiations observed between mother's and stranger's touch. Therefore, the **Hypothesis 3** needs to be rejected, since no significant differences were found between father's and stranger's touch.

Aim 2: Maturational differences

Hypothesis 4a predicted that there would be differences between second (younger) and third-trimester (older) fetuses, due to a more matured CNS. Specifically, more differentiated responses related to the source of the stimulus in the third-trimester compared to the second trimester were expected to be found. Findings from this experiment support **Hypothesis 4a** in that throughout the experiment consistent differences can be found between younger and older fetuses. Younger fetuses appear to be moving their arms and head significantly more compared to older fetuses. Younger fetuses also display more 'General movements' compared to older fetuses (DiPietro et al., 2015). Concordant results can be found in the opposite variables of 'Arms-crossed' and 'Inactivity/Resting', which shows that younger fetuses rest less compared to older fetuses who appear to be more inactive overall. In the domains of tactile response, younger fetuses appear to display more overall ‘External touch’ however upon further inspection of the interaction, it becomes apparent that younger fetuses appear to differentiate less between tactile conditions and respond in somewhat the same frequency and duration regardless of who touches. Older fetuses, in contrast, appear to be more selective and show a clear pattern in response to external tactile stimulation. Thus the calculated overall gestational difference between younger and older fetuses may in part be due to the averaging of the individual values of the responses. Thus although the overall gestational model suggests differences between the two groups as an increase in activity and external touch for younger fetuses it would be hasty to assume that younger fetuses differentiate between the touches as the further investigation of the interaction shows that the responses to tactile stimulation become a lot more varied and clearer in older fetuses, which suggests that fetuses CNS development is more advanced and that they do appear to discriminate between the different external tactile stimulants, more so than younger fetuses do. Thus we can accept **Hypothesis 4a** and assume that there are maturational differences between younger and older fetuses.

Hypothesis 4b hypothesised that third-trimester fetuses were likely to differentiate the touch of the mother compared to the control condition. The data from this experiment supports this hypothesis. Older fetuses showed a differential response in ‘Body touch’ and ‘Self touch’ throughout the stimulation period, where the fetus increased both variables during the control condition and decreased touch, while the mother was touching. While the mother was touching the fetus was showing more touch of the uterus than in the control condition. Furthermore, arms were crossed more during the control condition compared to when the mother touched her abdomen, suggesting that the fetus was less active and engaged in more self-directed stimulation when no external tactile stimulation occurred. Thus differential responses between the touch of the mother and the control condition were found and **Hypothesis 4b** is supported.

Hypothesis 4c hypothesised that third-trimester fetuses show a stronger differentiation to the tactile stimulation overall, compared to no-touch. This hypothesis is supported by our data. Differences cannot just be found between the control condition and mother's touch, but also between stranger's touch and the control condition. Fetuses appear to not just engage in 'Uterus touch' during the mother's touch but also tend to do more so during the stranger's touch compared to the control condition. During the first minute of stimulation, the response to the stranger is slightly stronger than that to the mother, this, however, begins to attenuate following the first 30s of stimulation, until the response to the stranger is shorter than that of the mother but still stronger than that to the father's touch.

The overall engagement in 'External touch' is also larger for father's and stranger's touch compared to the control condition during the first minute of stimulation. Interestingly changes in response durations for 'Body touch' can be observed during stranger's touch. During the first minute of stimulation, beginning immediately (0-15s), highest touch is found for the control condition, lowest for mother's touch, increasing ever so slightly for father's and stranger's touch. During the second minute of stimulation, however, the response to stranger's touch increases and is now in different from the control condition. Results for 'Self touch' remain stable throughout the whole stimulation period, with increased self-touch during control and less self-touch during all tactile stimulation conditions, during which the 'External movements' are much higher, showing that the fetus attempts to engage with the tactile stimulus and does not display such response during control, when there are no such stimuli present. None of the presented results were significant for second-trimester fetuses. The presented results indicate that the third-trimester fetuses show stronger differentiation to the tactile stimulation overall compared to a no-touch control condition, and thus **Hypothesis 4c** is supported by our data.

Hypothesis 4d: It was further hypothesised that older fetuses differentiate between the father and the stranger. The experiment expected to find stronger behavioural responses to the father's touch compared to the stranger's touch. The only difference in third-trimester fetuses was found for 'Body touch', where fetuses engaged in less 'Body touch' during father's touch compared to stranger's touch. The differences between father's and stranger's touch, however, did not reach statistical significance, thus despite one result, **Hypothesis 4d** needs to be rejected as there is not substantial evidence across variables to support the hypothesis.

Aim 3: Time interval analysis and detailed coding system

Hypothesis 5 examined fetal behavioural responses over different time-intervals and explored possible patterns in fetal responses over the course of the 2-minutes of stimulation. It was hypothesised that there will be differences over time-intervals.

Interestingly results can be seen immediately after the onset of stimulation across conditions. After inspecting the fuller picture of the data, it becomes apparent that the immediate response to tactile stimulation is an increase in activity, which is characterised by an increase in 'Arm movements', and shows the strongest initial response for mother's touch. Differences in 'Arm movements' disappear after 15s of tactile stimulation. As the 'Arm movement' activity beings to diminish differential responses in the form of 'Uterus touch' frequency emerge (0-15). Most frequent 'Uterus touch' responses are observed in response to mother's touch followed by stranger's touch. Responses to the father's touch and the control condition are somewhat similar. Overall, the strongest differential responses in form of 'Uterus touch' duration can be observed within the first minute of stimulation and its corresponding time intervals (0-30s, 30-60s, 0-60s). These findings further confirm that the fetus responds to the differential tactile stimuli. Especially to mother's touch, the fetus begins to respond by touching the uterus first more frequently and once the source of stimulation is found ‘Uterus touch’ frequency decreases as ‘Uterus touch’ duration increases and differences between the responses to different tactile stimuli become more differentiated. ‘Uterus touch’ remains a very strong variable throughout the experiment as the same pattern remains over the whole 2-minute (0-120s) period of stimulation.

Findings from the computed variable ‘Self-touch’, which is comprised of ‘Body touch’ and ‘Face touch’, underline the findings from ‘Uterus touch’ in that a matching pattern in ‘Self-touch’ also beings to emerge (0-10s, 0-15s, 0-30s) and stays constant around the same time as ‘Uterus touch’ duration (0-30s). During the first 0-10s of ‘Self-touch’ duration in older fetuses, the shortest self-stimulation can be observed in response to the mother’s touch, followed by the stranger’s and the father’s touch, and the longest ‘Self-touch’ duration can be seen in the control condition. In younger fetuses ‘Self-touch’ duration is the longest in response to the stranger’s touch followed by the control condition, and then mother’s and father’s touch. These patterns change slightly as the fetus continues to move in response to the stimulation (0-15s), with older fetuses touching the longest in response to stranger’s touch, followed by mother’s touch, the control condition and then father’s touch. Younger fetuses, on the other hand, show longer ‘Self-touch’ during the control condition, then father’s, mother’s, and stranger’s touch (0-15s).

The pattern begins to settle (0-30s) and will eventually remain the same throughout the remaining stimuli period (30-60s, 0-60s, 60-90s, 90-120s, 60-120s, 0-120s). The longest ‘Self-touch’ duration can be seen for control and stranger’s touch conditions, whereas in response to the mother’s touch fetuses show the shortest amount of ‘Self-touch’, and slightly more ‘Self-touch’ can be observed in response to father’s touch in third-trimester fetuses. The pattern for second-trimester fetuses, however, is, although stable over time, slightly different. Second-trimester fetuses display the longest ‘Self-touch’ in response to the stranger’s touch, followed by the control condition and father’s, and mother’s touch. Overall, ‘Self-touch’ and ‘Uterus touch’ remain rather stable throughout the experiment, after the first 30s of stimulation, with ‘Self-touch’ being the most consistent variable analysed throughout the experiment.

‘Face press’ frequency and duration show differences immediately (0-10s), with the longest and most frequent responses to the father’s touch, followed by the mother’s, stranger’s and the control condition. The same pattern can be found throughout 0-15s and 0-30s, however, frequency results appear to weaken until both ‘Face press’ variables eventually disappear from the 30s onwards. A possible explanation could be that the face of the fetus could have already been pressed against the uterine wall and begins to move away from the stimulus as ‘Arm movements’ increase, in order to make way for the hands touching the uterus (‘Uterus touch’). ‘Uterus touch’ comes to the fore from and during 0-30s, 30-60s 0-60s, and as it disappears again for 60-90s as ‘Face press’ becomes more differentiated.

Over the course of the stimulation, fetuses show significantly longer ‘Inactivity/Resting’ duration in response to father’s and stranger’s touch as well as the control condition. This pattern beings to evolve from 0-15s and becomes more prominent throughout the end of the third quarter of the first minute of stimulation (as it is not present in 0-15s but 0-30s) and continues throughout the experiment (30-60s, 60-90s), diminishing towards the last 30s of stimulation (from 60-90s to 90-120s). The fetus appears to be the most active in response to mother’s touch. Although the fetus responded with increased ‘Arm movements’ to the mother’s touch at the beginning of the stimulation (0-10s and 0-15s), these arm movements begin to disappear as the fetus increases ‘Uterus touch’ frequency and duration, and later on throughout the stimulation it can be seen that during mother’s touch the fetus is the least inactive (30-60s, 60-90s), and continues express increased ‘Hand movements’, possibly, along the inside of the uterus (90-120s).

Although the literature mainly focusses on the first minute of stimulation (Kisilevsky et al., 2003; Lee & Kisilevsky, 2013) the results can be found already within the first 10-15s of the stimulation. More so it has been shown that averaging out responses by investigating larger time frames, such as 1- and 2-minutes can result in overlooking delicate changes and findings. The interval analysis has provided further insight into the development of the response over time, highlighting periods of activity and periods where lack of movement appears to be more pronounced. Another insight gained from the evaluation of different intervals is that patterns within variables remain rather stable throughout the whole stimulation period, even if the intensity might change, or when the differences disappear they can re-emerge at a later point in time still display the same pattern.

Thus **Hypothesis 5** can be accepted as differences between different time-intervals were found.

General Discussion

These results support the observations by Valman and Pearson (1980) and Hooker (1952) that older fetuses tend to move towards sensory-motor stimulation (Hooker, 1952; Valman & Pearson, 1980). Similarly, to these observations older, third-trimester, but not the younger, second-trimester fetuses reached out to the uterus wall when the mother's abdomen was touched. The results also confirm our previous data that reported that fetuses, in particular in the third-trimester increase some of their movements as a response to the touch of the mother's abdomen (Marx & Nagy, 2015).

This differential response of the older fetuses might be due to the maturation of the central nervous system (CNS). During the third trimester of pregnancy, the CNS continues the maturation, neuronal differentiation, lamination, and the distribution of the thalamocortical axons. It is about between the 26-28th weeks of gestation when the peripheral nervous system connections with the CNS become functional (Klimach & Cooke, 2008; Kostović et al., 2002), which in turn, allows the fetus to process and to react to external somatosensory and pressure stimuli.

Mothers often and automatically rub their abdomen in a way that this activity often resembles a form of massage. Massage therapy under experimental conditions is usually applied to the hands, feet, neck, head, back in the mothers (Field, Hemandez-Reif, et al., 2009b) and has been found to be an effective intervention. Massage therapy reduced anxiety in pregnant women, in particular, anxiety during labour, decreased the levels of cortisol and norepinephrine (Field, 2010) and symptoms of depression in pregnant women (Field, Diego, et al., 2009a). Massage therapy showed to be superior even over relaxation therapies in reducing anxiety, pain, back pain, improving mood and sleep (Field, Diego, et al., 2009a). One of the main outcomes of massage therapy during pregnancy was the fewer complications during labour, improved neonatal outcomes as measured by the Neonatal Behavioural Assessment Scale (Brazelton, 1973) and the reduction of premature birth rate. The effects were maintained even when the massage was administered by the partner (Field et al., 2008).

Field and her colleagues proposed a model (Field, Diego, et al., 2009a; Morris & Weinstein, 1981) that explains how massage increases the level of serotonin and decreases norepinephrine and cortisol levels and in turn, decreases symptoms of depression, reduces leg and back pain, and anxiety. Such biochemical changes are suggested to lead to a lower rate of prematurity in the baby as one of the main outcomes of massage therapy research in pregnant women.

The nature of the touch, however, is also important. A reason the present study employed ‘calibration’ of the touch was that previous research found significant differences in the effects of light versus moderate pressure massage (Field et al., 2004; Field, Diego, et al., 2009a). Moderate but not light pressure stimulation activates the vagal nerve, and via vagal stimulation, influences the cardio-respiratory and gastrointestinal system, including increased absorption and motility (Field, Diego, et al., 2009a). The evolutionary newer branches of the vagal nerve also have a hypothesized function in promoting social affiliation and attachment (Porges, 1995). It is likely that mothers naturally use an optimally moderate pressure that is adjusted to their weight, body type and perhaps the stage of pregnancy, thus the feedback from the mother was essential to reduce the variability of the touch by the stranger and the father.

In order to minimize differences in the touching style and explore whether the mother’s touch is unique to the fetus and differences are not due to the application of a different tactile stimulation that varies in pressure, motion, and direction; the touching style was calibrated to match the mother's touch as much as possible. This way differential responses are not due to different touching styles but it allows to discriminate between the possible uniqueness of the mother’s touch compared to the externally applied touch of someone familiar and a stranger versus a control condition of no stimulation. Including only one source of external human touch would not be sufficient enough as fathers touch might be perceived differently by the mother or it might be more familiar to the fetus, which is why a stranger condition was included to provide an additional external tactile source. However, it might also be possible that the stranger’s touch is perceived differently by the fetus regardless of the prior calibration of the stimulation as it is might be interpreted differently by the mother, possibly resulting in a combination of neurological and physiological responses impacting upon the final tactile sensation the fetus is capable of perceiving (Christenfeld et al., 1997; Monk et al., 2000), as the mother tensing up or having differential hormonal responses to a stranger touching her bump (i.e. more tense, stressed) could alter the overall perception of the stimulation. It will, therefore, be interesting to see whether the responses to fathers and strangers touch are similar or not.

Although it is plausible to assume that fetuses would selectively respond to maternal touch via the abdomen and differently to the touch of the father and stranger, this assumption was not fully supported by the data. Fetuses reacted differently to the control condition compared to both when mother and stranger touched but not when the father touched the mother's abdomen. It is possible that the stranger, confederate experimenter, learned to rub the mother's abdomen quickly as she gained experience throughout the experiment – thus she was quicker in learning and adapting to different types and styles of touches the mothers taught her. It is likely that fathers slipped back into their usual style of touch they have always used when touching the mother's abdomen. It is also likely that the strength of the pressure differed and might not have consistently reached 'moderately' strong pressure to have an effect on the fetus. Another explanation for this finding is that differences between tactile stimulation and control were generally large enough to show a significant/tendency, however, the differences between the different types of tactile sources were not necessarily strong enough to result in such statistical significance. This does not necessarily mean that the results are not in the data, as the inspection of the means and corresponding graphs shows there are differences, however, due to the small sample size the standard error was too large, making it impossible to gain significance at this point.

Overall, older but not younger fetuses responded to the touch most differentially, rubbing of the maternal abdomen by moving towards the stimulus and touching the uterine wall. Older fetuses, therefore, were more capable of reacting differentially to stimulation versus no stimulation, compared to younger fetuses. Despite touch being amongst the first senses that develop at about the 8^{th} gestational week, it is not until the 32^{nd} gestational week when the skin of the fetus is fully developed, which might enable them to differentially respond to pressure and touch stimuli (Montagu, 1971). This general difference in the activity between age groups gave support to our earlier report (Marx & Nagy, 2015) that found that older fetuses spent a long time inactive with crossed arms, suggesting less motor activity, longer quiet periods overall.

Chapter 4

General Discussion

Addressing of the general aims

Overall, this thesis aimed to address two main aims. The aim of the first experiment was to address whether the fetus is capable of differentiating between different auditory stimuli, more specifically between different methodological presentations of the maternal voice. The maternal voice was presented in naturally occurring way – spontaneous live spoken voice rather than reading a story or 'motherese', which are most commonly used during experiments on the fetal responsiveness to the maternal voice (Kisilevsky et al., 2003; 2012; Krueger, 2010; Lee, 2010; Al Qahtani, 2005; Smith, Dmochowski, Muir, & Kisilevsky, 2007). In order to examine the fetal response to the mother's naturalistic voice, that the fetus must already be familiar with to some degree, depending on the advancement of the auditory development, fetuses were presented with both live spontaneous speech and recorded the spontaneous speech of the mother. As previously outlined, research examining fetal responsiveness to maternal voice commonly record the voice and then play it back onto the mother's abdomen. Playing a recording back to the fetus, however, could remove many unique characteristics of the maternal voice, such as bone conductivity, thus altering the voice, which potentially could result in a novel rather than a familiar stimulus. To address this question, Experiment 1 aimed to compare spontaneous maternal voice in situ, to the recorded voice of the mother. Based on the evidence from Experiment 1, fetuses did respond differentially to the two presentation methods of the mother's voice. Overall, there is evidence of emerging differential response patterns between these two conditions in conjunction with the two control conditions. Furthermore, older fetuses responded differentially compared too younger fetuses to the two voice conditions. However, similarities between the two voice conditions also remain, which is highlighted by the similar responses to these two maternal voice conditions when compared to control and everyday noise conditions.

A further important question to address was whether fetuses' behavioural responsiveness to maternal voice is unique over other commonly occurring sounds. This aim was addressed by comparing fetal behavioural responses to (1) naturally occurring maternal voice, (2) recorded maternal voice, and (3) a recorded everyday auditory stimulus, and a (4) control condition with no-auditory stimulation. Findings from Experiment 1 suggest that, although all conditions elicit a fetal response, the observed responses are unlike the predicted responses. Fetuses did not show differential responses between the three auditory stimulation conditions and control, no-stimulus condition, but rather show a response far more complex than anticipated, including maturational changes impacting upon the responses.

In summary, the main aim of Experiment 1 (see Chapter 2) was to examine whether fetal behavioural responses to social auditory stimuli are different from non-social stimuli and whether the fetus is able to discriminate between the mother's live and recorded voices. Overall it is suggested that fetal responses are indeed different between social and non-social auditory stimulation. Responses to the voice conditions elicited the strongest arousal responses from younger, second-trimester fetuses. Older fetuses, on the other hand, displayed an orientating response to the voice conditions, which was strongest for the live voice condition, although not statistically significant from the recorded condition, a tendency was visible within the data which should be further examined in future studies.

The aim of the second experiment was to investigate the effects of external tactile stimulation on the fetus. Experiment 2 explored fetal social responsivity in the tactile modality. This experiment aimed to provide insight into whether fetuses can discriminate between tactile stimuli of different origin. Previous research has suggested that the fetus displays a behavioural arousal response to maternal tactile stimulation when compared to her voice and a control condition with no stimulation. Experiment 2 aimed to systematically examine fetal responses to different kinds of touch (Marx & Nagy, 2015).

The mother's touch is an intentional pressure stimulus, moving the abdominal wall and the internal uterine environment to touch the fetus. Pregnant women engage in touching their 'baby bump' on a daily basis, both consciously and spontaneously. Previous research (Marx & Nagy, 2015) found that fetuses displayed increased arm, head, and mouth movements towards maternal touch when compared to their responses to maternal voice or a control, no stimulation condition. However, it remained unknown whether the maternal touch is a unique stimulus to the fetus, and whether the fetus is capable of discriminating between the touch of different origins, such as father's or stranger's touch. Findings from experiment 2 (see Chapter 3), support the predictions that the mother's touch is a special tactile stimulus for the fetus. The strongest responses were found to the mother's touch in comparison with other tactile stimuli, and the non-tactile control condition.

It is expected that fetuses can perceive both auditory and tactile stimulation (Birnholz & Benacerraf, 1983; Caulfield, 1999; Gerhardt & Abrams, 1996; Hall, 2000; Perdigoto et al., 2014; Querleu et al., 1988; 1989), and in some extent, are conscious and intentional in their responses according to the nature and the origin of the stimulation (Castiello et al., 2010; Delafield-Butt & Gangopadhyay, 2013; Myowa-Yamakoshi & Takeshita, 2006; Zoia et al., 2007). Our previous study (Marx & Nagy, 2015) provided evidence for such differential responsivity, hence the two experiments, Experiment 1 and 2, were designed to separately address these two modalities, unlike the previous study where both modalities were cross-compared directly (Marx & Nagy, 2015). Furthermore, based on the reviewed literature a difference between gestational ages was expected. Findings from both experiments support the notion that gestational differences impact upon the kind of response the fetus displays. Generally, it appears as if the second-trimester fetus is more easily arousable than the older fetuses are. It is most likely that this difference is due to older-fetuses being more familiar with the presented stimuli and that they have increased inhibitory capabilities thus are capable to respond with an orientating response instead of an arousal response.

The importance of the mother-infant relationship has long been of interest to developmental researchers and has given rise to the idea of the importance of the mother to the newborn as a special stimulus. The earliest studies investigating neonatal responses to maternal voice discovered that newborns prefer their mother's voice over that of a stranger (DeCasper & Prescott, 1984). Studies on preterm infants have shown the benefit of neonatal stimulation using human voices, especially mother's voice, in the neonatal intensive care unit (Filippa et al., 2013; Klimach & Cooke, 1988; Krueger, 2010; Picciolini et al., 2014; Saliba, Esseily, Filippa, Kuhn, & Gratier, 2018). Moreover, a recent meta-analysis examining previous research on the importance of maternal voice on the preterm newborn found increases in feeding skills, oxygen saturation, behavioural measures, respiratory and heart rate studies (Saliba et al., 2018). This link between neonatal developmental advantages and newborn preference to the mother's voice suggests that at some point during pregnancy, the fetus begins to familiarise itself to the maternal voice. Although the evidence clearly suggests that the fetus is able to recognise the mother's voice, it remains unclear during which developmental period the fetus begins to respond and discriminate the mother's voice from other voices (Cave et al., 2015; Krueger et al., 2004; Krueger & Garvan, 2014; Lecanuet et al., 1986; Lecanuet, Fifer, & Krasnegor, 2013; Lee, 2010; Shahidullah et al., 1994; Voegtline et al., 2013; Webb, Heller, Benson, & Lahav, 2015). The uncertainty is due to methodological complications of the voice presentation, as well as the kind of measurements taken, which we will be discussed in the following sections.

A recent study has investigated the emergence and retention of a rhyme, to which the fetus had been exposed to on a daily basis from 28 wGA (Krueger & Garvan, 2014). The rhyme was read aloud by the mother in motherese, as newborns have been found to prefer motherese over normal spoken voice (Cooper & Aslin, 1994). Fetuses were tested repeatedly between 28-38wGA.

Results showed that changes began to emerge from 34wGA and were significant from 38wGA. However, the testing was actually done by presenting the fetus with a female stranger's voice and not the mother's voice. Although Krueger et al. (2014) claim that the passage was not remembered until 38wGA, the study might have actually measured familiarisation to another female's voice, rather than to the passage itself. In order to measure whether the fetus is capable of remembering the familiarised passage it would have been more beneficial to examine responses to the mother's reading, rather than a stranger. The literature investigating fetal responsiveness is often met with such methodological challenges. Most of the time researchers do not examine fetal responses using live and naturally occurring voice but present the stimulus using a tape recording, or present the stimulus in a peculiar way, for example by using rhymes or motherese, which are both unfamiliar to the fetus and therefore are poor measures of their ability to recognise the mother. Measuring responses to pre-exposed stimuli, such as nursery rhymes, is more likely to measure early learning and memory functioning rather than the uniqueness of maternal stimuli to the fetus. Thus, although many studies have investigated the effects of maternal voice on the fetus, and the results remain rather inconclusive, overall they appear to suggest that the fetus is capable of responding differentially, and recognising the mother, familiar passages, and languages some time during the third trimester (Jacquet et al., 2009; Kisilevsky et al., 2003; Krueger et al., 2004; Krueger & Garvan, 2014). Early research has, however, shown that the fetus is capable of responding to auditory stimuli much earlier (Hepper, 1991; Shahidullah & Hepper, 1994). Our research supports the notion that the fetuses are indeed capable of responding differentially to mother's live spoken voice during the second-trimester of pregnancy. Second-trimester fetuses from this study were between the ages of 21-27 wGA, and showed the strongest responses to spontaneous maternal live voice, followed by the maternal recording condition. Responses to both voice conditions were also different from control conditions, but not necessarily dissimilar to each other, suggesting that the fetuses were already capable of responding and recognising the mother earlier than previously reported. For third-trimester fetuses the differences between to the two voice conditions diminished, and responses to the voice conditions were similar to the control condition, and only small non-significant differences could be seen between the recording and the live condition. There appeared to be a tendency of the recording to elicit a minimally stronger arousal response compared to the live condition, possibly due to the unnatural source of the voice which is probably related to a loss of physical acoustic cues, such as bone conductivity and vibrations. Thus Experiment 1 furthered our understanding of fetal responses to naturally occurring maternal voices, and suggests that differential responses are already to be found within the second-trimester.

Time-Interval Analysis

Further analysis of the experiments has allowed highlighting the immediacy of the fetal response. Earliest responses for both, voice and touch experiments, show responses within the first 0-10 seconds of stimulation. These responses grow stronger over the following seconds so that most significant results, which remain consistent during the first minute of the stimulation, are significant within the 0-30 seconds' time interval. The responses do not remain the same throughout the 2-minutes of stimulation. Responses decrease during the second half of the stimulation (60-120 seconds) suggesting that habituation of the fetus to the stimulus has taken place. From the touch experiment it becomes apparent that, during the second half of stimulation (60-120 seconds), the fetus engages in more resting behaviours. This manifests itself in the increased body touch and arms-crossed positioning, as compared to increased frequencies and durations of uterus touch, during the first half of the stimulation. This implies that the fetal response is time-sensitive, and therefore time-intervals need to be considered for accurate interpretation. Although some researchers (Jacquet et al., 2009) have previously argued that the examination time-frame needs to be increased as fetal responses may take longer to emerge than previously examined, this time analysis of two sensory commodities suggests otherwise. Our research suggests that fetal responses can be observed almost immediately and begin to decline following the first minute of stimulation. It would, however, be of interest to examine once the social stimulation stops, to see whether the fetus will initiate interaction. Once the stimulation has disappeared the fetus might attempt to engage in ‘communicational’ attempts, by touching the uterus from the inside or kicking in order to provoke a response from the mother. It would even be possible for late-term fetuses to initiate the first proto-conversations through interacting with the maternal abdomen.

Fetal movements as a tool to assess fetal development and responsiveness

The main experimental stream, in the literature, investigating the effects of external stimulation on the fetus have so far relied heavily on the examination of FHR measures in response to an auditory stimulus, most often familiarised passage read aloud by the mother and played back to the fetus (DeCasper et al., 1994; Hepper, 1991; Hepper & Leader, 2010; Kisilevsky et al., 1992; 2012; Kisilevsky & Hains, 2011). However, studies focusing solely on FHR response measurements appear to keep reporting inconclusive results. Results either show a FHR acceleration (DeCasper et al., 1994) or a deceleration (Kisilevsky & Hains, 2011). Closer examination of voice presentation methodology (live or recorded) highlighted differences in FHR responses for the two methods, with an acceleration to the tape recording and a deceleration in response to the live voice (Cave et al., 2015). Differences in fetal general movements were also examined, and no differences were found between the presentation methods (Cave et al., 2015). Results from this study support these findings (Cave et al., 2015) only partially. Thus, as the use of FHR responses has previously been shown to record unreliable results across studies (DeCasper et al., 1994; Kisilevsky et al., 1992; 2012; Kisilevsky & Hains, 2011), the examination of general movements has been found to be inconclusive and incongruent with results from FHR measurements (Cave et al., 2015), the employment of a detailed movement response system could prove itself to be a more reliable measurement of fetal examination and development.

The results from both experiments examined fetal responses using a detailed movement response coding system, instead of only focussing on general movements. Regarding auditory stimulation (see Chapter 2) it was observed that second-trimester fetuses did indeed show differential behavioural responses between both maternal voice conditions. This highlights how easily important results can be lost by focussing solely on the overall movement responses. The early differentiation examined using a detailed movement approach does support results suggesting earlier differentiation, measured using FHR responses (DeCasper et al., 1994; Kisilevsky et al., 1992; 2012; Kisilevsky & Hains, 2011). Thus, it can be agreed that even younger fetuses are capable of responding to maternal auditory stimulation with differential movements, unlike previously reported (Cave et al., 2015).

This begs the question as to why not more researchers have employed the use of detailed movement coding. Investigating FHR is certainly the easiest way of examining fetal responsiveness, as the placement of the fetal Doppler is rather simple and effortless, and the obtained readings are readily available for further analysis. The employment of ultrasound as a methodology for fetal responsiveness observation, on the other hand, requires not just great patience and skill, but subsequent processing of the behavioural videos, which is very time-consuming. The acquired video data requires frame-by-frame behavioural coding, which prepares the data for further statistical analysis. This type of research is therefore difficult to conduct in most laboratories due to the lack of time, skill, and access to equipment, although it provides scientists with valuable information about the developing fetus.

Therefore, the main improvement from both conducted experiments of this thesis, compared to the majority of previously conducted experiments in the literature, lies in the detail of the coding system. Where other studies relied heavily on the observation of general, unspecified, movements (Shahidullah & Hepper, 1994; Stanojevic, Zaputovic, & Bosnjak, 2012), the two experiments from this thesis utilised a detailed coding system, which focuses on individually quantifiable movement observation. The use of a sensitive measurement allows to examine the fetal responses in detail and can provide us with further information on the fetal neurobehavioural development.

Fetal movements have the potential to elucidate the scientific understanding of prenatal neurobehavioural development. Observations utilising ultrasound have investigated the development of the fetal movement repertoire which revealed coordinated and intentional movements from as early as 12 wGA (de Vries et al., 1982; 1985; 1988; Lüchinger et al., 2008; Piontelli, 2015; Zoia et al., 2007). Throughout gestation, the repertoire increases underpinning the gradual structural development of the fetal CNS (Eyre et al., 2000). Although the fetal nervous system appears rather primitive, it is already capable of goal orientated anticipation and basic intentionality of movements for both self-directed movements (Zoia et al., 2007) as well as early social twin interactions (Castiello et al., 2010). Action planning of socially directed movements between twins are based on social cues and primitive perception of these appears possible in-utero (Castiello et al., 2010).

Despite the environmental changes, induced by labour, which result in the loss of special restrictions of the uterine environment and results in the induction of gravity of the extra-uterine environment and release of uterine special restrictions, one would assume that it the fetal movement repertoire experiences certain alterations and adjustments, yet regardless of these environmental changes continuity between prenatal and postnatal movements have been observed (Stanojevic et al., 2012). Similar kinematic upper limb movements have been observed between fetuses and newborns, suggesting that it would be possible to follow up prenatal to postnatal behaviours through alteration of prenatal kinematic observations (Zoia et al., 2013). Further analysis of kinematic measurements would, therefore, allow it to further investigate the issue of movement continuity between a fetus and newborn. This will help gain further insight into the development and connection of movement and neural development, since the full-term fetus is already equipped with the same neurobehavioural repertoire as a newborn and the neural development progresses systematically, highlighted by the presence of mature function patterns throughout the course of pregnancy (DiPietro et al., 2015).

Thus it has been proposed that fetal kinematics are a valuable tool for investigating prenatal cognition, as well as pre-to-postnatal continuity outcomes (Castiello & Parma, 2017). Examining fetal activities throughout gestation reveals the blueprint of the structural CNS development (Eyre et al., 2000). The anticipation of goal orientated movements have already been revealed using kinematics, and intentionality has been related to the fetal behaviours (Castiello & Parma, 2017). It has also been suggested that brain areas involved in action initiating movements are dependent on motivational processes, which is connected to consciousness and emotion (Ellis & Newton, 2012). Ellis & Newton (2012) have argued that consciousness can only occur if an organism is capable of anticipating self-motivated actions. This, in turn, would imply the possibility for the fetus to be capable of experiencing the most basic form of consciousness in utero.

The observation of both qualitative and quantitative movement patterns can possibly allow for early identification of typical and atypical development (Eyre et al., 2000). Researchers have therefore suggested that the analysis of fetal movements represents a good tool for discovering early pathologies in utero, which otherwise would not manifest until much later in life (Castiello & Parma, 2017). However, more research needs to be conducted in order to generate a normal movement profile before the examination and diagnosis of abnormal behaviour can be used to diagnose atypically developing fetuses (Castiello et al., 2010; Castiello & Parma, 2017; Eyre et al., 2000; Piontelli, 2010; Zoia et al., 2007).

The ‘sociality’ of the fetus

A full-term fetus has the same neurobehavioural repertoire as a newborn and the development progresses systematically throughout pregnancy. Mature patterns of function are evident throughout pregnancy and have therefore led to the conclusion that a pre-term newborn is the same as a fetus in the ‘wrong environment’ at the ‘wrong time’ (DiPietro et al., 2015). Newborns show a preference for familiar languages, television theme songs, nursery rhymes (Fifer & Moon, 1995). Researchers, therefore, believe that the pre-exposure to environmental sounds aids familiarisation with the ex-uterine environment, predisposing the newborn to its social environment (DeCasper & Fifer, 1980; DiPietro et al., 2015; Al Qahtani, 2005; Spence & Freeman, 1996). This highlights the connectedness between the fetus and the newborn in a way that it is no longer possible to claim that the fetus is unaffected and oblivious to the external environment whilst in-utero. The senses and necessary brain areas are developed enough to allow for the experience and retention of, in this case, audible stimuli, and most likely other sensory stimulation such as tactile stimulation of the maternal abdomen, which is directly related to the external tactile stimulation the fetus can perceive.

Researchers argue that the newborn is born into this world ready for social interaction (Bard, 2007; Nagy & Molnar, 2004; Trevarthen, 2009). The pre-term newborn is developmentally seen the same as a fetus in the wrong environment at the wrong time (DiPietro et al., 2015), thus it is feasible to imply that prenatal stimulation such as voice or touch might play an important role in preparing the developing fetus for a world of social interactions.

Tactile stimulation is thought to aid the development of a very basic me/not me body schema discrimination (de Preester & Knockaert, 2005; Gallagher, 2006) from early on in the development. Body schema is an unconscious awareness of the own body in space in relation to posture and movements. Gallagher (2006) argues that in the most primitive way, proprioceptive awareness is a form of self-consciousness of the embodied self, which begins its development in utero. It is in a way a part of the sense of self; however, it is more closely related to an embodied sense rather than a psychological or cognitive understanding. It can be hypothesised that changing body movements and the sensation of touch in utero aid development of a sense of self in space (Trevarthen, 1980), which will develop further once the fetus is born (Piontelli, 2010). A slightly different angle on the topic of the sense of self is the account for a ‘minimal sense of self’ (Gallese & Sinigaglia, 2010). The minimal sense of self-focusses on the consciousness of the body as a subject of the action (Gallese & Sinigaglia, 2010). Regarding the sense of agency, the minimal sense of self-assumes that the agent is the one generating the action. Ownership, on the other hand, relates to the agent being the one undergoing the experience, regardless whether the experience is generated internally or externally (Gallagher, 2006; Gallese & Sinigaglia, 2010). The minimal sense of self, however, must be in connection with the bodily sense of self, which can be assumed to be the most primitive sense of self, which has been given to us as a powerful source of action in order to interact with the environment (Gallese & Sinigaglia, 2010). The body acts as a source of sensory stimulation, be it seeing with our eyes or touching with our hands and body, as both commodities allow us to perceive and interact with the surrounding environment independently. Touch, contrary to vision, is a bidirectional sense, it simultaneously allows to touch and to be touched by another person or object, and allows to access the world and objects in it, unlike any other sense. This way of accessing and interacting with the world intentionally has been proposed as primary (Merleau-Ponty, 1962). Therefore, the sense of body is a necessity upon which the sense of self and agency can be built and developed upon (Gallese & Sinigaglia, 2010). The body schema combines motor intentional features and the integration of multiple sensory modalities and first appliances of this behaviour can possibly be observed in-utero. The fetus appears to make use of the body schema by interacting to and with the tactile stimulation of the maternal abdomen. Responses could be observed across stimulation conditions compared to the control condition. Thus the fetus appeared to engage with the tactile stimulation. Further differences were observed between age groups and their tactile response patterns, where responses from second-trimester fetuses appeared to be rather similar within the group across conditions, but different to the response of the third-trimester fetuses. Third-trimester fetuses were more discriminative to the tactile stimulation, compared to second-trimester fetuses, suggesting a more advanced body schema, supposedly partially explaining the increased motor intentionality and goal-directed movements towards the stimulus source for older fetuses (Castiello et al., 2010; Zoia et al., 2007).

Voice or other auditory stimulation, such as music (Partanen et al., 2013), on the other hand, has been shown to enhance various brain functions through morphological and biochemical changes, when played at optimum levels (Alladi, Wadhwa, & Singh, 2002; Gottlieb, 1963; 1985; Panicker, Wadhwa, & Roy, 2002). These direct effects were first found in bird embryos, where learning ability was improved after prenatal sound stimulation (Lickliter, Bahrick, & Honeycutt, 2002). Further research by Lickliter and his research group has unravelled a series of studies on the pre- and postnatal effects of sensory stimulation on cognitive development and perceptual learning (Bahrick & Lickliter, 2002; Harshaw & Lickliter, 2011; Honeycutt & Lickliter, 2002; Lickliter et al., 2002; Lickliter & Virkar, 1989). This work has pioneered the understanding of how different types of prenatal auditory stimuli can alter postnatal behaviour of birds. Although the majority of this research was conducted on animals, the similarities between mammalian and avian species are closely related, especially regarding their neurodevelopment (Lickliter & Bahrick, 2007). Stimulation early in life can alter and modify neural connectivity which could possibly lead to long-term changes in plasticity if exposed frequently. Auditory stimulation has been suggested to modify neural plasticity during both pre- and postnatal periods of development, impacting upon neurogenesis of the hippocampus (Jáuregui-Huerta et al., 2011), noise processing in the prefrontal cortex (Ghim, Baeg, Kim, & Jung, 2011) and emotion processing in the amygdala even into adulthood (Wallentin et al., 2011). Thus investigating effects of early prenatal auditory exposure, utilising auditory stimuli such as the mothers voice, who have been shown to be a special stimulus to the fetus and newborn (Beauchemin et al., 2010; DeCasper & Fifer, 1980; Saint-Georges et al., 2013; Webb et al., 2015), has the possibility to modify various neural functions while the brain is still undergoing continuous pruning and in turn have positive effects on the developing individual. Although full functionality of fetal hearing is not established until the third trimester, we have found evidence of early fetal responses to maternal voice and it would be of great interest to further explore the longitudinal outcomes of positive social auditory stimulation on postnatal cognitive development. Additionally, the sound of a positive social stimulus is associated with emotion processing and could be linked with up-regulation of neural pathways (Aguado et al., 2003; Rossi et al., 2006). Thus being surrounded by a socially enriched environment carries possible positive effects on the neural development of the infant and premature (Lee, Mikesell, Joaquin, Mates, & Schumann, 2009) and possibly the fetus, too. The newborn has not engaged in direct touch, until now, as all the external abdominal stimulation was modified by the abdominal wall prohibiting skin-to-skin stimulation, which is connected to the affective touch system (Löken et al., 2011; McGlone et al., 2012; Olausson, Wessberg, Morrison, & McGlone, 2016; Vallbo et al., 2016). Touch immediately following birth elicits a neurobiological response where the opiate system is activated, which produces a consummatory reward for the newborn (Lee et al., 2009). The formation of memories based on previously encountered experiences leads to the development of the seeking of a dopamine-related reward. Oxytocin and vasopressin levels can increase or decrease the saliency of the affiliative stimuli (Eriksson, Lundeberg, & Uvnäs-Moberg, 1996). Oxytocin is indirectly affecting the dopaminergic and opiate reward system, thus interplaying with reward-seeking behaviours (Csiffáry, Ruttner, Tóth, & Palkovits, 1992). This would have a positive effect on the seeking of tactile stimulation, which in turn releases oxytocin in the newborn, feeding the feedback cycle. Oxytocin plays an important role in the human body, facilitating bonding between mother and child. When mother and newborn come into contact, the release of oxytocin in to the mother’s bloodstream starts the production of milk and leads to the dilation of the cutaneous blood vessels of the mother’s chest leading to increased warmth transfer to the newborn during breastfeeding (Eriksson et al., 1996). The release of oxytocin also contributes to the general well-being of both parties, and reducing stress and releasing endorphins (Uvnäs-Moberg & Petersson, 2005; Uvnäs-Moberg, Widström, Marchini, & Winberg, 1987). It has been proposed that a positive environment as well as social interaction continuously activate this system (Uvnäs-Moberg & Petersson, 2005).

The opposite holds true for growing up in a sensory deprived environment (Carlson & Earls, 1997; Frank et al., 1996; Gonzalez et al., 2001; Gunnar, 2001; Schanberg & Field, 1987). Adverse effects of sensory deprivation on normal emotional and social functioning and behaviour have been reported in both human and animal studies, suggesting that social enrichment is vital for normal neurological and psychological development across species (Champoux, Higley, & Suomi, 1997; Chugani et al., 2001). Effects of increased social stimulation have been related to increased responsiveness in chicks (Honeycutt & Lickliter, 2003). Thus there is evidence for positive longitudinal outcomes of social developmental for both, humans and animals. Positive stimulation has been proposed to affect the development of various brain regions related to learning, memory, and behaviour and this nature and nurture interaction requires further exploring in order to discover how social environmental stimulations can accompany and help normal development. In relation to the developing fetus, it can be observed that the fetus moves in response to maternal stimulation. It could, therefore, be hypothesised that increased maternal social stimulation has a positive effect on fetal neurological development and should, therefore, be reinforced (Jacquet et al., 2009; Kisilevsky et al., 2003; Krueger, 2010; Marx & Nagy, 2015; Webb et al., 2015).

Overview summary tables of the voice experiment and touch experiment visualising all analysed time-intervals, can be found in Tables 4.1 & 4.2, and Tables 4.3 & 4.4, respectively. It can be seen that the fetus responds to both, voice and tactile stimulation within the earliest interval periods (0-10 and 0-15sec). In the voice experiment it is highlighted that the second-trimester fetuses respond with increased ‘Arm movements’ to the mother’s voice, whereas third-trimester fetuses respond with a decrease and possible orienting response. This response is likely to be due to the increased familiarity of the mother’s voice to the third-trimester fetus. For the touch experiment it can be seen that the third-trimester fetus responds with an arousal response to the mother's touch, and expresses externally directed movements in the form of hands touching the uterine wall, during the first minute of stimulation. During the second minute of stimulation the fetus decreases its movements and increases 'Face press' against the uterine wall, possibly to increase the surface for external tactile stimulation. Medium strong responses were found for father's touch, and minimal responses were found to stranger's touch.

From the tables below it becomes obvious that the application of a detailed coding system can be of great advantage when trying to understand the complexity of the fetal response to external stimulation. Simply focussing on general movements or even just FHR responses leads to the missing out of delicate responses. These subtle responses are already observed within newborn research and should also be employed in fetal research.

The implementation of interval analysis can further the understanding of the complexity of the fetal response dialogue with the external stimuli. Averaging the response across a 2 minute period leads to the loss great detail as can be seen in the tables (4.1, 4.2, 4.3, & 4.4) below. The response data proposes a communicative response with turn taking and would be missed when time-intervals are disregarded.

These responses can be seen as a preparation and early development of social interactions and may indicate the emergence of a primitive proprioceptive self-awareness by the 3rd trimester (Gallagher, 1995). Furthermore, increased fetal maturation and familiarisation with the maternal stimuli allows for later recognition of the primary caregiver necessary for fetal survival.

Table 4.1. Overview: Voice experiment results summary for all time intervals (in seconds): Standard variables. (Conditions: L= Live, R= Recording, N= Noise, C= Control; 2= second trimester, 3= third trimester; *= significant between conditions, += tendency between conditions, cGA= interaction between condition and gestational age, GA= Gestational age; trend/significant repeated ANOVA, trend/significant mixed ANOVA)

	0-10	**0-15**	**0-30**	**0-60**	**30-60**	**60-90**	**60-120**	**90-120**	0-120
Facepress F	Condition C<N+	Condition C<N+	Condition C<N+	Condition C<N+	Condition C<N+	Condition C<N*	Condition C<N*	Condition C<N*	Condition C<N+
	Condition C<N+	Condition C<N+	Condition C<N+	Condition C<N+	Condition C<N+	Condition C<N*	Condition C<N+	Condition C<N+	Condition C<N+
Facepress D	Condition C<N +	Condition C<N+	Condition C<N+	Condition C<N*	Condition C<N*	Condition C<N*	Condition C<N*	Condition C<N*	Condition C<N*
	Condition C<N	Condition C<N+	Condition C<N+	Condition C<N+	Condition C<N+	Condition C<N*	Condition C<N*	Condition C<N*	Condition C<N*
Arm movement F	cGA L 3<2+	Condition N<L+	GA 3<2+	cGA L 3<2*		cGA L *			cGA L 3<2*
	cGA R 3<2+	GA 3<2+	cGA L 3<2*	cGA R 3<2+		cGA 2 N<L*			cGA R 3<2+
		cGA L 3<2*	cGA R 3<2*	cGA N 3<2 +		cGA 2 N<R+			cGA 2 N<L*
		cGA R 3<2*	cGA N 2<3*	cGA 2 N<L*					GA 3<2*
		cGA N 2<3*	cGA 2 N<L*	cGA 2 N<R+					
		cGA 2 C<L+	cGA 2 N<R+						
		cGA 2 N<L*							
		cGA 2 N<R+							
Arm movement D		cGA L 3<2*	cGA L 3<2*	cGA L 3<2*					cGA L 3<2*
		cGA R 3<2+	cGA R 3<2+						
		cGA 2 C<L*	cGA 2 N<L*						
		cGA 2 N<L+	cGA 2 N<R+						
Uterus Touch F	cGA L 3<2*	cGA L 3<2*	cGA L 3<2*	cGA L 3<2*	cGA L 3<2*	cGA L *3<2			cGA L 3<2*
	cGA N 2<3+	cGA N 2<3+	cGA N 2<3*	cGA N 2<3+	cGA N 2<3+	cGA 2 N<L+			cGA N 2<3+
	Condition N<R+	cGA 2 N<L*	GA 3<2+	cGA 2 N<L*	cGA 2 R<L*				
	cGA 2 N<L*		cGA 2 N<L*		cGA 2 N<L*				
	cGA 2 N<R*		cGA 2 N<R+						
Uterus Touch D	cGA L 3<2+	cGA L 3<2*	cGA L 3<2*	cGA L 3<*2	cGA L 3<2*				cGA L 3<2*
	cGA N 2<3+	cGA N 2<3+	cGA N 2<3+	cGA N 2<3+	cGA 2 N<L*				cGA 2 N<L*
	cGA 2 N<R+	cGA 2 N<L+		cGA 2 N<L*					
		cGA 2 N<R+							
Hand movement F			cGA R 3<2+						
Body Touch F				cGA N 2<3+	cGA Condition 3<2+				cGA -
					cGA N 2<3+				
Face Touch F				cGA L 3<2*					
				cGA R 3<2*					
Sucking F				GA 2<3+					
Yawning F						Condition -			
Head movement D		Condition -							
Arms crossed F								cGA R 3<2*	
								cGA 2 C<R*	
								cGA 2 L<R+	
Arms crossed D								cGA R 3<2*	
								cGA 2 C<R+	

Table 4.2. Overview: Voice experiment results summary for all time intervals (in seconds): Combined variables. (Conditions: L= Live, R= Recording, N= Noise, C= Control; 2= second trimester, 3= third trimester; *= significant between conditions, += tendency between conditions, cGA= interaction between condition and gestational age, GA= Gestational age; trend/significant repeated ANOVA, trend/significant mixed ANOVA)

	0-10	0-15	0-30	0-60	30-60	60-90	60-120	90-120	0-120
Inactivity/Resting F							Condition -	cGA R 3<2* cGA 2 C<R+ cGA 2 L<R+	
General Movement F	cGA -	Condition - GA 3<2+ cGA R 3<2* cGA L 3<2+ cGA N 2<3+ cGA 2 N<R* cGA 2 C<R+ cGA 2 N<L+	cGA R 3<2* cGA N 2<3+ cGA 2 N<R*				GA 3<2*	GA 3<2*	
General Movement D		cGA R 3<2* cGA 2 C<L*	cGA L 3<2+ cGA 2 N<L+				GA 3<2*	GA 3<2*	
Self-touch F				cGA -		Condition C<R*			
External F		cGA 3 C<N*	cGA L 3<2+	cGA L 3<2*	cGA L 3<2*				
External D			cGA 3 C<N*	cGA N 2<3+	cGA N 2<3+ cGA 2 R<L*				

Table 4.3 Overview: Touch experiment results summary for all time intervals (in seconds): Standard variables. (Touch conditions: M= Mother, F= Father, S= Stranger, C= Control; 2= second trimester, 3= third trimester; *= significant between conditions, += tendency between conditions, cGA= interaction between condition and gestational age, GA= Gestational age; trend/significant repeated ANOVA, trend/significant mixed ANOVA)

	0-10	0-15	0-30	0-60	30-60	60-90	60-120	90-120	0-120
Arm movement F	Condition - Condition -	Condition - Condition -				Condition - Condition -	Condition F<M+ Condition F<M+		
Arm movement D	GA 3<2+								
Face press F	Condition - Condition C<F+	Condition - Condition C<F+	Condition - Condition C<F+			Condition - Condition C<M+ Condition C<F+			
Face press D	Condition - Condition C<F+	Condition - Condition C<F+	Condition - Condition C<F+	Condition C<F+		Condition - Condition C<M+ Condition C<F+	Condition F<M+		
Uterus Touch F		cGA F 3<2*	cGA Condition 3<2+ cGA F 3<2*	GA 3<2+					
Uterus Touch D			cGA C 3<2* cGA S 2<3* cGA 3 C<S+	cGA C 3<2* cGA S 2<3* cGA 3 C<S+ cGA 3 C<M+	cGA C 3<2* cGA S 2<3+ cGA 3 C<M*		Condition -		cGA C 3<2* cGA S 2<3+ cGA 3 C<M+ cGA 3 C<S+
Body Touch F	cGA 3 M<C+ cGA C 2<3+	cGA C 2<3* cGA 3 F<C+	cGA C 2<3+ cGA 3 F<C+	cGA 3 F<C+			Condition - Condition M<C+ cGA M 3<2+ cGA S 2<3+ cGA 3 M<C* cGA 3 M<S* cGA 3 F<S+	Condition - Condition -	
Mouth movement F						Condition - Condition - cGA 2 C<S* cGA 2 M<S*			
Mouth movement D						cGA 2 M<S+ cGA 2 F<S+	cGA -		cGA -
Head movement F				GA 3<2+	Condition - Condition - GA 3<2+				
Arms-crossed F	GA 2<3+						Condition M<C* Condition M<C* cGA S 2<3+ cGA 3 M<C+ cGA 3 M<S*	Condition M<C+ Condition M<C* cGA S 2<3+ cGA 3 M<C* cGA 3 M<S*	
Arms-crossed D	GA 2<3*	GA 2<3*	GA 2<3*	GA 2<3*	cGA S 2<3* cGA 3 M<S* GA 2<3+		Condition - cGA S 2<3* cGA 3 M<C+ cGA 3 M<S*	Condition M<C+ cGA S 2<3* cGA 3 M<C* cGA 3 M<S*	cGA S 2<3* cGA 3 M<S*

Table 4.4. Overview: Touch experiment results summary for all time intervals (in seconds): Combined variables. (Touch conditions: M= Mother, F= Father, S= Stranger, C= Control; 2= second trimester, 3= third trimester; *= significant between conditions, += tendency between conditions, cGA= interaction between condition and gestational age, GA= Gestational age; trend/significant repeated ANOVA, trend/significant mixed ANOVA)

	0-10	0-15	0-30	0-60	30-60	60-90	60-120	90-120	0-120
Inactivity/Resting F	Condition S<M+				Condition M<S+	Condition M<C*	Condition M<C*	Condition -	
	Condition S<M+				Condition M<S+	Condition M<S*	Condition M<S+	Condition M<S+	
						Condition M<F*	Condition M<F+		
						Condition M<F*	Condition M<C+		
						Condition M<S+	Condition M<F*		
						Condition M<C+	Condition M<S+		
Inactivity/Resting D	Condition S<M*		Condition M<S+	Condition M<S+	Condition M<S+	Condition M<F+	Condition M<F+		Condition M<F+
	GA 2<3+		GA 2<3+	Condition M<S*	Condition M<F*	Condition M<F+	Condition -		Condition -
					Condition M<F+				
General Movement D	GA 3<2+				Condition M<S*				
Self-touch D	cGA S 3<2*	cGA M 2<3*	cGA C 2<3*	Condition -	Condition M<C+	Condition M<C*	Condition M<C*	Condition M<C+	Condition M<C*
		cGA S 2<3+	cGA S 3<2+	cGA C 2<3*	Condition M<C*	Condition M<S*	Condition M<S+	Condition M<C+	Condition M<C*
		cGA 2 M<C*	cGA 3 S<C+	cGA S 3<2*	cGA C 2<3*	Condition M<C*	Condition M<C*		cGA C 2<3+
		GA 2<3+		cGA 3 M<C*	cGA S 3<2*	Condition M<S+	Condition M<S+		cGA S 3<2*
				cGA 3 S<C+	cGA 3 M<C*				cGA 3 M<C*
					cGA 3 S<C+				cGA 3 S<C*
Self-touch F			cGA -					Condition -	
								Condition -	
External-touch F				GA 3<2*	GA 3<2+				
External-touch D				cGA C 3<2*		Condition -			
				cGA 3 C<F+		Condition -			
				cGA 3 C<S+					

Future directions and limitations

Both experiments from this thesis would have benefitted from a larger sample size. Apart from the significant results, many possible differences were revealed, which are implied by the observed tendencies. Increasing the number of participants could strengthen the statistical analysis and possibly explain further behavioural results. A further benefit of including more participants is the possibility to include more gestational groups or, with a very large sample, look at the weekly fetal developmental advancements. The most effective way of doing so would be a longitudinal design, ideally following up on the newborn and infant's development. The employment of a longitudinal study could investigate several interesting topics such as the development of responsiveness, neurobehavioural development, memory, attention, executive functioning, temperament and personality, possible indicators for health development, and social development. It would also allow us to explore possible correlations regarding continuity between a fetus and newborn infant.

Ideally, future experiments would measure both detailed movement responses and FHR responses. This would allow a comparison between the two and possibly shed light on the previous disagreements in the literature.

Improvements on the voice experiment could be made by including another female voice, such as a stranger, both live and recorded, to compare the fetal reactions too. Including another female voice and examining fetal movements compared to the mother's voice and control conditions could help shed light on how the fetus processes and responds to auditory stimulation, using varying methodologies. This kind of design would complement previous studies investigating FHR measurements. It would allow us to see how the fetal movement responses change and or correspond with the FHR measurements. Another interesting addition to the experiment would be the introduction of father's voice. However, the inclusion of the father's voice would require controlling for the pre-exposure to the voice. This means to say that fetuses who are exposed to the father's voice more, as compared to fetuses who are not exposed to the father's voice much might respond differentially. Thus further measurements would need to be taken to control for the exposure and familiarity to the father's voice.

Improvements on the touch experiment could be made on the calibration of the touch. In this experiment, the stranger and father were asked to touch the same way the mother touches. This was done to ensure that the reactions of the fetus are not due to different tactile stimulation, in terms of pressure and movement pattern, and to ensure the safety of the fetus. However, it would be interesting to see how the fetus reacts to the natural touch of a father and stranger in comparison with the calibrated tactile stimuli.

A touch paradigm could also be employed to investigate fetal responses to different types of touch, which could help gain interesting insights into the developmentent of fetal memory and habituation to different tactile rhythms. The fetus could be pre-exposed to the tactile rhythm over a prolonged period of time prior to the experiment. By employing a longitudinal design fetal responses could be examined over the course of gestation. This would allow gaining a greater understanding of the response development over the time. One could examine how long it takes the fetus to habituate to the stimulus during each session, while simultaneously observing how the type of response might change as the fetal motor development advances. It would also allow examining during which gestational week the fetus has truly habituated to the stimulus. The obtained results could then be compared with findings from other habituation studies, which so far have only ever investigated the habituation to voice and vibrations. Comparison of critical response periods would allow gaining insights relating to memory formation from different sensory inputs. As the two senses begin developing at different times, and tactile development precedes auditory development, it is possible that this approach offers further insight into the cognitive development of the fetus.

On another note, it would also be of interest whether increased tactile stimulation and engagement between mother and fetus could have positive effects on neonatal neurodevelopmental and behavioural outcomes. Research during the early postpartum days has already shown that increased maternal touch positively alters maternal behaviour (Klaus et al., 1972). After the intervention mothers found it harder to leave their newborns with someone else, showed greater interest in infant examinations, displayed improved soothing behaviour, and increased fondling and eye-contact (Klaus et al., 1972). In order to examine this paradigm ethically on the fetus, neonatal behavioural outcomes would be compared between mothers who have engaged in ‘normal’ tactile stimulation and enhanced tactile stimulation group. The enhanced tactile stimulation group could be asked to touch their abdomen daily, for a certain amount of time, over a prolonged period of time, ideally during the last two trimesters. Both groups would need to take note of the amount of tactile engagement, which might allow for further forming of tactile engagement groups. It is likely that the naturally engaging group could be split into two further groups, one with mothers who naturally engage less and one for mothers who naturally engage frequently. This set-up would also allow for further examination of increased tactile stimulation on the effects of maternal-fetal attachment. It is possible that increased engagement with the fetus, and therefore the pregnancy, results in increased attachment between mother and fetus (Kim et al., 2014; Siddiqui & Hagglof, 2000). It could be possible that the engagement could be used as an intervention for mothers with low attachment to increase maternal-fetal attachment and thus increase the relationship between the mother and her child. 3D ultrasound studies have already shown an increase in maternal attachment following a prenatal ultrasound scan (Sedgmen et al., 2006). This intervention would beneficial to both, mother and infant, as it has been shown that increased stress (elevated cortisol) during pregnancy impacts negatively upon long-term infant cognitive development, which in turn negatively impacts upon the mother-infant relationship (Bergman et al., 2010). Thus it is of interest to create and sustain a stable maternal-fetal attachment and following mother-infant relationship, in order to prevent impaired cognitive infant development, which in the long run can lead to increased health problems, such as, cardiovascular disease, cancers, asthma, osteoporosis, diabetes, and neuropsychiatric disorders in adulthood (Gillman, 2005).

All mothers in both experiments of this thesis were highly attached to their fetuses. Research has shown that decreased maternal attachment is associated with decreased maternal postnatal engagement with the baby (Siddiqui & Hagglof, 2000). Thus, it would be of interest to see how naturally low attached mother's fetuses would respond to maternal social stimulation compared to highly attached mothers. It is most likely that fetuses of less attached, and therefore engaged, mothers are also less responsive. It is likely that the mother's stimulation is not very familiar to the fetus, due to the lack of stimulation and engagement of the mother. Mother's with low attachment could be given tasks to engage with their fetuses on a daily basis, such as talking to or touching their abdomen, in order to examine whether fetal responsiveness improves. This would also allow examining whether the mother-fetus relationship could be enhanced by means of maternal interaction with the fetus. It has already been shown that maternal-fetal attachment can be increased through the means of 4D ultrasound scans (Honemeyer & Kurjak, 2014). These, however, are expensive and not easily accessible to all mothers. Finding a 'cheap' alternative intervention which can enhance mother-fetus/infant relationship would be of benefit to all mothers. Especially mothers from low socioeconomic backgrounds with irritable infants would benefit from free home-based interventions. Studies have shown that infants from a low socioeconomic background benefit greatly from increased maternal sensitivity interventions, increasing infant's scores on self-soothing, sociability, exploration, and reducing crying (van den Boom, 1994). Thus in order to give every human-being the best possible start and life outcomes, it is of great interest to find readily available measures for early interventions during sensitive developmental periods, i.e. during pregnancy.

The relationship between low attachment and other mental disorders such as depression or anxiety could be further explored. Research has shown that depressed mothers are less engaged in their pregnancy (Ferber, 2004) and that increased prenatal maternal cortisol levels are related to decreased attachment (Bergman et al., 2010). It would be plausible to assume that depressed mothers are less attached to their fetus. This, in turn, can lead to a less responsive fetus, as studies with depressed mothers have already indicated fetuses to habituate quicker, thus being more passive and less responsive (Dieter, Emory, Johnson, & Raynor, 2008; Field, Diego, & Hernandez-Reif, 2006). A less responsive fetus is likely to be a less engaged newborn and more difficult child to handle for the mother.

Studies investigating the comorbidity between prenatal maternal anxiety and depression link negative neonatal and fetal outcomes such as growth impairments, prematurity, and decreased fetal responsiveness to biochemical changes such as decreased levels of dopamine and serotonin and increased levels of cortisol and norepinephrine (Emory & Dieter, 2006; Field, Diego, Hernandez-Reif, Figueiredo, et al., 2010b). Studies investigating the effects of antenatal maternal depression and anxiety on infant development revealed increased negative behavioural reactivity in infants, therefore suggesting a link between mother's psychological condition and long-lasting impact on infant behaviour (Davis, Snidman, Wadhwa, & Glynn, 2004). It would be possible that the earlier proposed, auditory and tactile interaction, during pregnancy, could help reduce the effects of anxiety, prenatal and postnatal depression on the fetus and its neonatal outcomes.

Conclusion

The two conducted empirical studies provide insights into fetal development to auditory and tactile stimulation. Differential responses in the voice experiment (see Chapter 2) were found for younger fetuses. Responses were the strongest for maternal stimuli, with a tendency to be the strongest for the live voice condition. Comparison with responses to the noise condition found further evidence that the mother is a unique stimulus to the fetus. Younger fetuses showed significantly different responses compared to older fetuses, especially regarding the voice conditions. This suggests that younger fetuses display an arousal response whereas older fetuses display an orienting response to the mother's voice. Younger fetuses have not been exposed to the mother's voice as much, since responses to sound are only found from 16 wGA with all fetuses responding by 28 wGA (Brezinka et al., 1997; López-Teijón et al., 2015; Sohmer, Perez, Sichel, Priner, & Freeman, 2001), which includes our young fetuses sample (20-28 wGA). Older fetuses are more familiar with the mother's voice and decrease their activity when the mother speaks. Overall, younger fetuses were found to be more active in their responses, whereas older fetuses displayed less activity. The time-interval analysis shows that the fetuses respond immediately to the mother's voice and most prominent responses are found within the first minute of stimulation. Response patterns vary over the course of stimulation, thus highlighting the importance of the time relevant analysis.

The touch experiment (see Chapter 3) investigated fetal responses to differential human tactile stimuli and is the second experiment investigating responses to maternal touch and the first to investigate differential responses between mother's, father's, and stranger's touch. As predicted, differential stimuli to the different tactile stimuli were found. Overall, strongest responses were found for mother's touch, followed by father's and stranger's touch, and the control condition. Contrary to the voice experiment, older fetuses showed a more varied response to the differential tactile stimuli. Strongest externally directed movements were found in response to the mother's touch over the other tactile stimuli, suggesting that the mother's touch is special to the fetus and it engages in reciprocal uterus touch, possibly engaging in a basic form of a response feedback or even antenatal 'proto-conversation'. Younger fetuses, on the other hand, did not show differential responses between the tactile stimuli. It is possible that the transition from perceiving to responding to tactile stimulation happens during the end of the second-trimester since responses of third-trimester fetuses are very pronounced. Although touch is the first sense to develop, at about 8 wGA, it is not until 32wGA that the skin of the fetus is fully developed, which might result in differential responses to pressure and tactile stimulation (Montagu, 1971). Time-sensitive results were also observed in this experiment, and similar events to the voice experiment were observed. Responses to tactile stimuli were also immediate and strongest during the first minute of stimulation. Afterward differential activity responses began to decline and the fetus engages in more resting behaviours. Both experiments, therefore, stress the importance of time-dependent analysis, as the responses of the fetus vary across time important data is lost through averaging out results. It is possible that the observed transitions, between gestational ages, and individual differences are reflective of the developmental advancement and continuity from fetus to newborn and infant (DiPietro et al., 2015).

These two experiments add important groundwork to the existing literature investigating fetal responsiveness and development. Although it remains unclear what the exact fetal movement responses mean, it is evident that the fetus responds and discriminates between different tactile and auditory stimuli. Being familiar, recognising, the mother's voice is vital for fetal survival once born (Alegria & Noirot, 1978). Research has already established that the newborn prefers the mother's voice over any other voice (DeCasper et al., 1994; DeCasper & Fifer, 1980) and that premature newborns benefit from hearing the mother's voice (Cevasco, 2008; Filippa et al., 2013; Krueger, 2010). The mother is the primary caregiver as the newborn will be highly dependent on her for a long time. Being able to recognise the mother by her voice, when the newborn has never seen her before, allows forming that connection. Maternal touch of the newborn has been found to be developmentally beneficial (Feldman, Weller, Sirota, & Eidelman, 2002b; Moore, Anderson, Bergman, & Dowswell, 2012), especially when born premature (Feldman, Weller, Sirota, & Eidelman, 2002a; 2002b; Neu et al., 2008), which allows to speculate that tactile engagement with the abdomen, and consequently the fetus, has beneficial effects on both the fetus and outcomes in infant development (Abdallah et al., 2013; Field, 2010; Procianoy et al., 2010). Tactile stimulation has been found to be beneficial across species and for humans no just in the context of premature interventions but also in the social domain. The perception of touch, especially social touch, has its own neural system devoted to it (CT-afferents) (Gordon et al., 2011; 2013; Löken et al., 2011; McGlone et al., 2012; Olausson et al., 2016) and social implications of touch can elevate, for example, feelings such as social exclusion, separation, or rejection suggesting a link to social bonding (Mohr, Kirsch, & Fotopoulou, 2017). Therefore, it could be suggested that abdominal antenatal maternal touch possesses the capability to help form the first bond between mother and fetus. Younger fetuses do not appear to respond as strongly to the tactile stimulation, whereas older fetuses do, and they appear to reciprocate by touching the uterine wall when the mother touches.

Both, mother's voice and touch, are important for the connection between mother and child and increased interaction is likely to have the possibility to increase mother-fetus/infant attachment (Branjerdporn, Meredith, Strong, & Garcia, 2016). Attachment is a bidirectional connection, meaning that both, mother and fetus, need to attach to each other (Brandon, Pitts, Denton, Stringer, & Evans, 2009; Klaus et al., 1972). As the newborn infant is dependent upon its primary caregiver, it is vital for the infant to familiarise itself with the mother and, in a way, establish a prenatal relationship. Thus, prenatal-interaction, through both commodities, auditory and tactile stimulation, is arguably at the core of building a live-long and healthy symbiotic relationship between mother and child (Kim et al., 2014), promote healthy development of both mother and child (Abdallah et al., 2013; Feldman, Weller, Sirota, & Eidelman, 2002a; Moore et al., 2012), and supposedly builds the foundation for love.

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Appendix

1. Participant Information Sheet

Does the fetus differentiate between the mother's voice, a tape recording, and everyday noise?

INVITATION TO TAKE PART IN A RESEARCH STUDY

I am Viola Marx, a PhD student at the University of Dundee. As part of my thesis, I aim to examine how the unborn babies behaviour changes when the mother interacts with the baby with her voice in comparison to everyday noise. I would like to ask you to participate in my study and be part of a simple experiment, where you would receive a 4D ultrasound scan, during which we will ask you to engage with your unborn baby by talking. We will also record your voice in order to play it to the baby during the experiment. The session will be videotaped for possible later analysis. Afterward, you will be asked to complete two brief questionnaires on your mood.

TIME COMMITMENT

The study will take about 60 minutes at the Developmental Neuropsychology Laboratory at the University of Dundee, School of Psychology.

COST, REIMBURSEMENT, AND COMPENSATION

Your participation in this study is voluntary and there are no costs. You will receive a free 4D video of your unborn baby as a token of our gratitude.

RISKS

There are no known risks involved in this study. The University of Dundee Ethics Committee has reviewed and approved the study.

The experimenter who performs this ultrasound, while qualified to provide such ultrasound services, is not a doctor, nurse or healthcare provider, and cannot interpret, diagnose medical conditions from, or otherwise offer medical conclusions regarding the images produced.
By participating in this study you understand that you are responsible for contacting your own healthcare provider if you have questions concerning this ultrasound or any other aspects of your pregnancy. Although the study is not concerned with disorders of mental health, if you think you suffer from related disorders, please consult your GP.

CONFIDENTIALITY/ANONYMITY

No one will be able to link the data provided to your identity or name. The data will be seen only by the researchers and will not be made available to anyone else. The data will be stored at the Developmental Neuropsychology Laboratory at the University of Dundee, in a securely locked cabinet. The data will be destroyed after five years.

TERMINATION OF PARTICIPATION

You may stop taking part in the study at any time without giving an explanation, and there is no penalty if you do stop, you will still receive your 4D video.

FOR FURTHER INFORMATION ABOUT THIS RESEARCH STUDY

If you have any questions in regard to this study then please get in touch. You can e-mail me at vmarx@dundee.ac.uk or my supervisor Dr. Emese Nagy at e.nagy@dundee.ac.uk [tel.no: 01382384613; full postal address: School of Psychology, University of Dundee, Park Place, Dundee, DD1 4HN).
If you would like to know the results of the study these will also be made available at the end of the study via e-mail.

2. Consent Form

Does the fetus differentiate between the mother's voice, a tape recording, and everyday noise?

This study is interested in how the unborn baby responds to maternal input such as maternal voice and everyday noise. You will receive a 4D ultrasound scan and then will ask you to complete two brief questionnaires on your mood. The session will also be videotaped.

By signing below you are indicating that you have read and understood the Participant Information Sheet and that you agree to take part in this research study. We want to thank you again for your time and participation.

Participant's signature Date

Participant's name

Experimenter's Signature Date

Experimenter's Name

I GIVE PERMISSION TO BE VIDEOTAPED FOR THIS STUDY.

YES ☐

NO ☐

Note: If you do not give permission to be videotaped, unfortunately we cannot involve you in the study

I GIVE PERMISSION TO HAVE MY VOICE RECORDED FOR THIS STUDY.

YES ☐

NO ☐

Note: If you do not give permission to have your voice recorded, unfortunately we cannot involve you in the

You can also agree for the footage to be shown to students for teaching purposes or to other researchers at academic conferences, but this is not a necessary part of the study. The images shown would not include anything that would identify either you or your baby. Please indicate your decision below:

Yes ☐

No ☐

3. Demographic Questionnaire Experiment 1

Personal Contact Details:

Name ___________________________________

Address ___________________________________

____

Telephone Number ___________________________

Date of Birth: ________________________________

Current Marital Status: (please tick)

Single

Married

Living with partner

Separated / Divorced

Widowed

How old were you when you left full-time education? ____

What is your level of educational attainment? (please tick)

No qualifications

Standard Grade(s)/GCSEs/O-Level(s)/O-Grade(s)

Higher(s)/Higher Skills/A-Level(s)

NC/HNC/Diploma

Degree (eg. BSc, Phd)

Your occupation? ________________________

Do you smoke? (please tick)

Yes – if yes, how many a day? ____

No

If no – did you smoke before you were pregnant?

Yes – if yes, how many a day? ____

No

What is your baby's gestational age? ____

Were there any complications during this or previous pregnancies?

(please tick)

Yes. If yes - current or previous? _________

No

If yes, what were they? ____

How many other children do you have? ____

How many pregnancies did you have in total (including this one)? ____

How old are they? Please list dates of birth

____

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____

How do you plan to give birth?

____

Are you planning on attending/attending antenatal classes? (please tick)

Yes

No

How much time do *you* spend: (please indicate in hours per day)

Talking to the baby? ____

Touching/Stroking the baby bump? ____

How much time do *other family members* spend: (please indicate in hours per day)

Talking to the baby? ____

Touching/Stroking the baby bump? ____

How much time do *strangers* spend: (please indicate in hours per day)

Talking to the baby? ____

Touching/Stroking the baby bump? ____

4. Questions for Experiment 1 on maternal voice

- What’s keeping you busy these days?

- How is work?
    Are you on maternity leave yet? If so do you enjoy it?
        What do you do with your time?
    No, when will it be? How do you feel about it?

- How are the preparations for the baby going?
    What do you need to prepare?
    How do you manage to organize everything, do you get help?

- How would the perfect day look like for you at the moment?

- Have you watched any movies lately? What about?
    What kind of movies do you like?
    do you watch any series? What are they about?

- Did you get away this summer?
    Do you go on many holidays? What do you enjoy most about them?

- How was your day so far? How did you get here?

- What are you getting up to today/tonight?

- Anything planned for the weekend?

- How are your other children doing?

- Do you have any pets? What are they up to?

- If you could change something about the world what would it be and why?

- When was the last time you laughed so hard you cried? Why?

- Do you have any hobbies? tell me about them

- How would the perfect evening look like for you at the moment?

5. Participant Information Sheet

Does the fetus differentiate between mother's, father's and stranger's touch?

INVITATION TO TAKE PART IN A RESEARCH STUDY

I am Viola Marx, a PhD student at the University of Dundee. As part of my thesis, I aim to examine how the unborn baby's behaviour changes when the mother interacts with the baby by stroking the stomach.

I would like to ask you to participate in my study and be part of a simple experiment, where you would receive a 4D ultrasound scan, during which we will ask you to engage with your baby by stroking your stomach with your hand. We will also have your partner stroke your stomach with their hand. And finally, an experienced female member of staff will stroke your abdomen. She is a qualified medical doctor, and you will meet her before the procedure begins. The session will be videotaped for possible later analysis. Afterward, you will be asked to complete two brief questionnaires on your mood.

TIME COMMITMENT

The study will take about 50 minutes at the Developmental Neuropsychology Laboratory at the University of Dundee, School of Psychology.

COST, REIMBURSEMENT, AND COMPENSATION

Your participation in this study is voluntary and there are no costs. You will receive a free 4D video of your unborn baby as a token of our gratitude.

RISKS

There are no known risks involved in this study. The University of Dundee Ethics Committee has reviewed and approved the study. The experimenter who performs this ultrasound, while qualified to provide such ultrasound services, is not a doctor, nurse or healthcare provider, and cannot interpret, diagnose medical conditions from, or otherwise offer medical conclusions regarding the images produced. By participating in this study you understand that you are responsible for contacting your own healthcare provider if you have questions concerning this ultrasound or any other aspects of your pregnancy. Although the study is not concerned with disorders of mental health, if you think you suffer from related disorders, please consult your GP.

CONFIDENTIALITY/ANONYMITY

No one will be able to link the data provided to your identity or name. The data will be seen only by the researchers and will not be made available to anyone else. The data will be stored at the Developmental Neuropsychology Laboratory at the University of Dundee, in a securely locked cabinet. The data will be destroyed after five years.

TERMINATION OF PARTICIPATION

You may stop taking part in the study at any time without giving an explanation, and there is no penalty if you do stop, you will still receive your 4D video.

FOR FURTHER INFORMATION ABOUT THIS RESEARCH STUDY

If you have any questions in regard to this study, then please get in touch. You can e-mail me at vmarx@dundee.ac.uk or my supervisor Dr. Emese Nagy at e.nagy@dundee.ac.uk [tel.no: 01382384613; full postal address: School of Psychology, University of Dundee, Park Place, Dundee, DD1 4HN).

If you would like to know the results of the study these will also be made available at the end of the study via e-mail.

6. Consent Form

Does the fetus differentiate between mother's, father's and stranger's touch?

This study is interested in how the unborn baby responds to maternal input such as maternal, partner's, and stranger's touch. You will receive a 4D ultrasound scan and then will ask you to complete two brief questionnaires on your mood. The session will also be videotaped.
By signing below you are indicating that you have read and understood the Participant Information Sheet and that you agree to take part in this research study. We want to thank you again for your time and participation.

______________________________ _______________

Participant's signature Date

____

Participant's name

______________________________ _______________

Experimenter's Signature Date

____

Experimenter's Name

I GIVE PERMISSION TO BE VIDEOTAPED FOR THIS STUDY.

YES ☐

Note: If you do not give permission to be videotaped, unfortunately we cannot involve you in the study.

NO ☐

You can also agree for the footage to be shown to students for teaching purposes or to other researchers at academic conferences, but this is not a necessary part of the study. The images shown would not include anything that would identify either you or your baby. Please indicate your decision below:

Yes ☐

No ☐

7. Demographic Questionnaire Experiment 2

Personal Contact Details:

Name ______________________________________

Address ______________________________________

____

Telephone Number _____________________________

Date of Birth: __________________________________

Current Marital Status: (please tick)

Single

Married

Living with partner

Separated / Divorced

Widowed

How old were you when you left full-time education? ____

What is your level of educational attainment? (please tick)

No qualifications

Standard Grade(s)/GCSEs/O-Level(s)/O-Grade(s)

Higher(s)/Higher Skills/A-Level(s)

NC/HNC/Diploma

Degree (eg. BSc, Phd)

Your occupation? __________________________

Do you smoke? (please tick)

Yes – if yes, how many a day? ____

No

If no – did you smoke before you were pregnant?

Yes – if yes, how many a day? ____

No

What is your baby's gestational age? ____

Were there any complications during this or previous pregnancies? (please tick)

Yes. If yes - current or previous? _________

No

If yes, what were they? ____

How many other children do you have? ____

How many pregnancies did you have in total (including this one)? ____

How old are they? Please list dates of birth

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How do you plan to give birth?

____

Are you planning on attending/attending antenatal classes? (please tick)

Yes

No

How much time do **you** spend: (please indicate in hours per day)

Talking to the baby? ____

Touching/Stroking the baby bump? ____

How much time does **your partner** spend: (please indicate in hours per day)

Talking to the baby? ____

Touching/Stroking the baby bump? ____

How much time do **other family members** spend: (please indicate in hours per day)

Talking to the baby? ____

Touching/Stroking the baby bump? ____

How much time do **strangers** (friends, co-workers, etc.) spend: (please indicate in hours per day)

Talking to the baby? ____

Touching/Stroking the baby bump? ____